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**OCTOBER
1957**

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IN THIS ISSUE:

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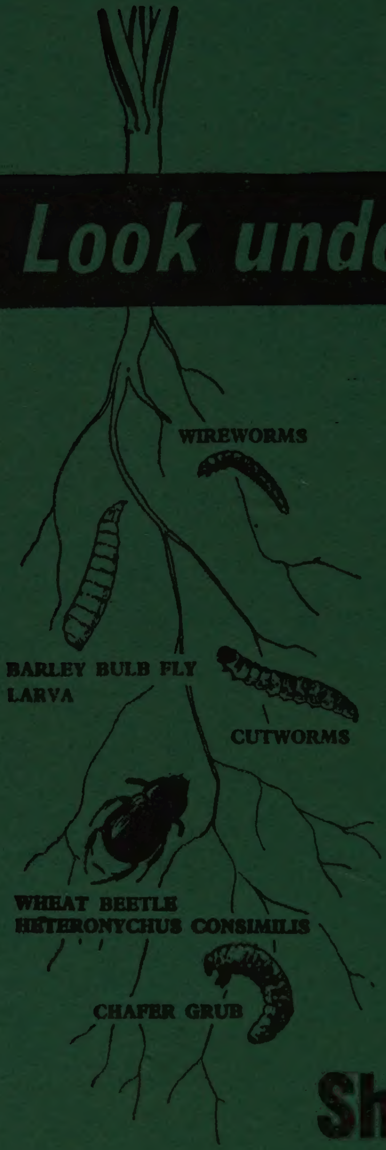

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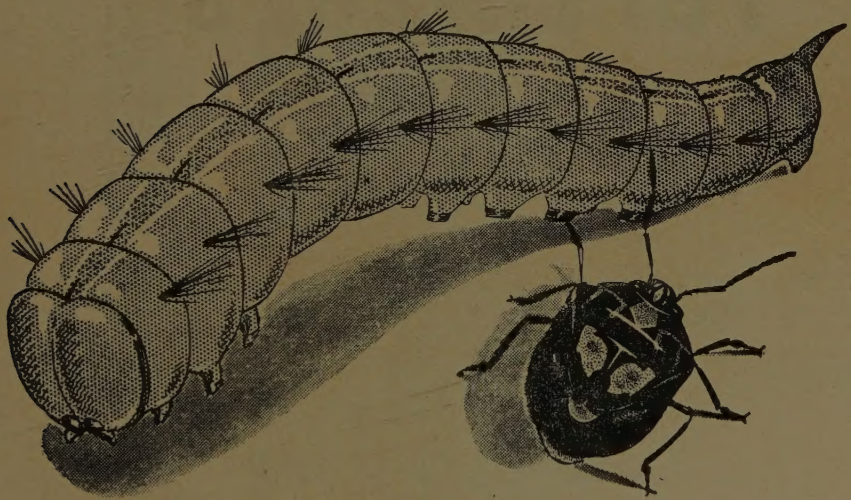

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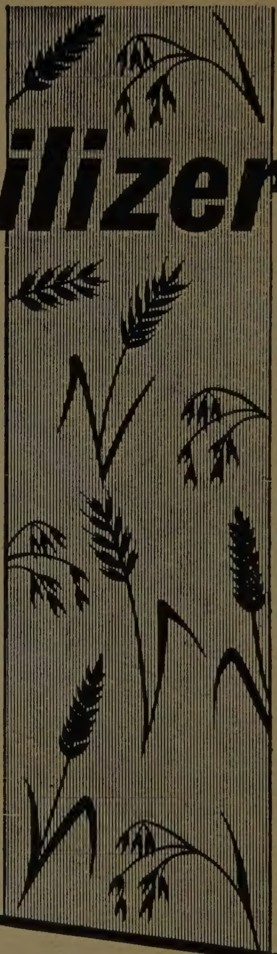

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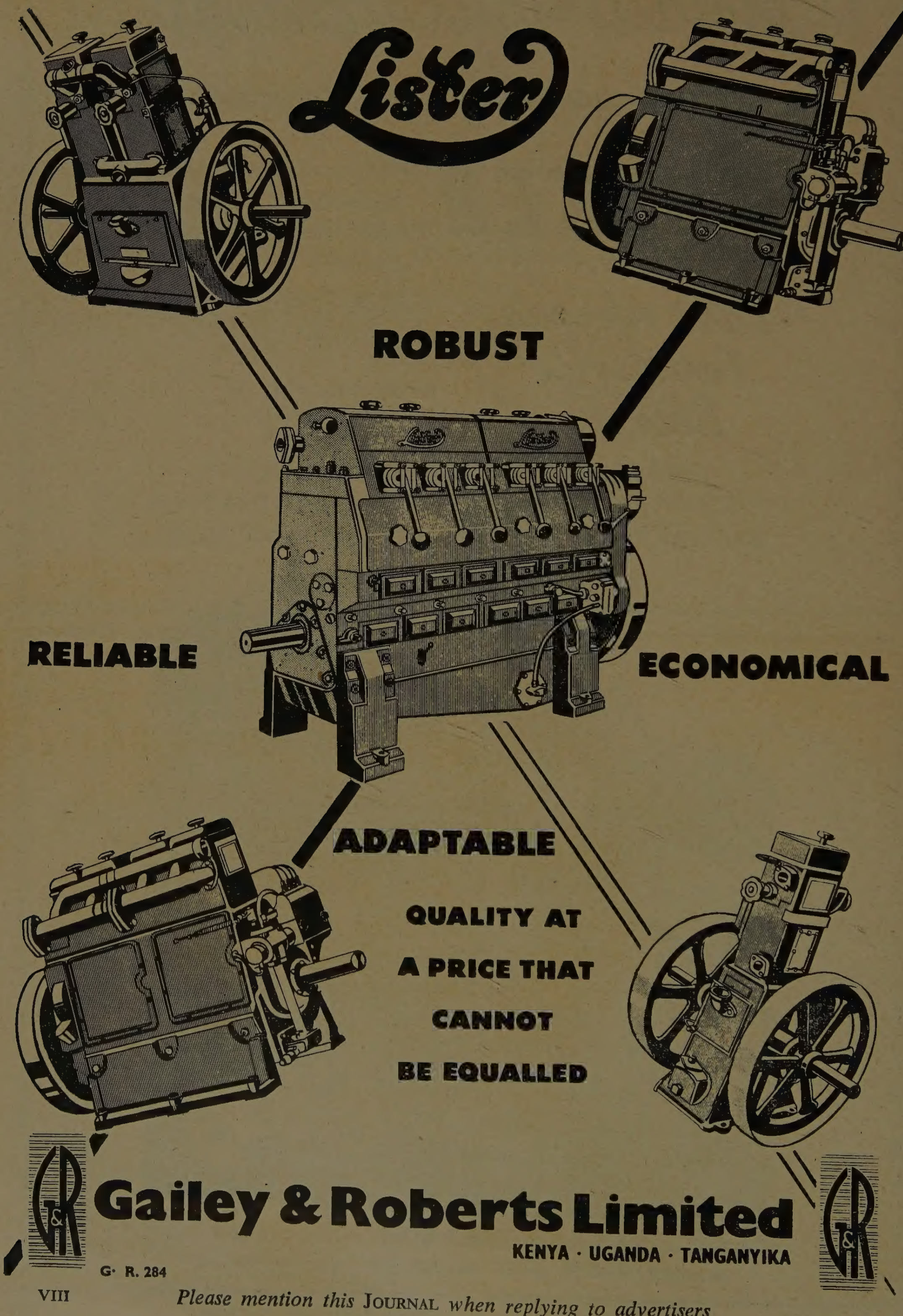
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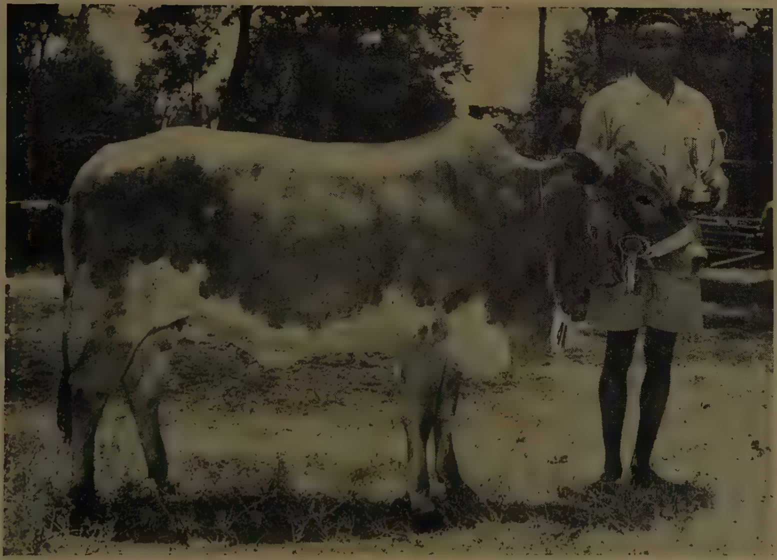

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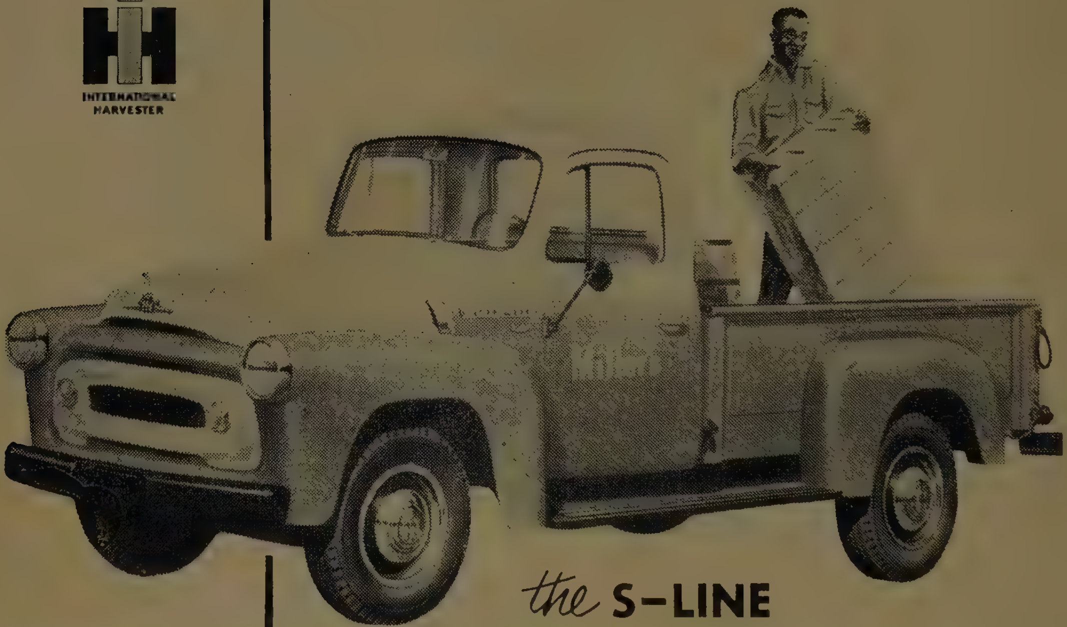

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Vol. XXIII—No. 2 **OCTOBER, 1957**

Printed and published by the Government Printer, Nairobi

Issued under the Authority of the East Africa High Commission and published every three months—July, October, January, April. Volume consists of four issues (commencing July issue)

Editorial Board: Director of E.A. Agriculture and Forestry Research Organization, Director of E.A. Veterinary Research Organization, Directors of Agriculture, Kenya, Tanganyika, Uganda and Zanzibar. Directors of Veterinary Services, Kenya, Tanganyika and Uganda. Conservators of Forests, Kenya, Tanganyika and Uganda.

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Subscription Sh. 10 per volume including postage, payable to the Editor. Subscribers are advised to remit postal orders in payment, otherwise bank commission must be added in the case of cheques.

The Editor does not hold himself responsible for opinions expressed by contributors.

Matter submitted for publication should preferably be sent through the local member of the Editorial Board. Double spacing should be used in typescript. Contributors receive 25 prints of their articles free. Additional copies may be obtained on payment if asked for in advance. Prints bear the same page numbers as the original articles in the Journal, except where, to meet a contributor's wishes, prints are supplied before publication has been completed.

Readers are reminded that all agricultural inquiries, whether they relate to articles in the Journal or not, should be addressed to the local Director of Agriculture, and not to the Editor.

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THE EAST AFRICAN AGRICULTURAL JOURNAL

DEVELOPMENT AND FARM PLANNING IN THE AFRICAN AREAS OF KENYA*

By L. H. Brown, Department of Agriculture, Kenya

(*Received for publication on 5th April,* 1957)

At the present time the African areas of Kenya are in the early stages of an agricultural revolution which is unique among British Colonies. This agrarian revolution is the outcome of polices which have been worked out over the past ten years, and the Swynnerton Plan, often quoted in the Press, is an intensification and acceleration of work that was already in progress before the outbreak of the Emergency. It does not involve any radical change of policy with regard to African agriculture.

All the policies at present in force in African areas in Kenya have been based upon the natural ecology of the country. It is felt that the natural vegetation is the best indication available of the potential of any area of land, resulting as it does from the sum of effects of rainfall, soil type and temperature. Rainfall in itself is an insufficient indication and so is soil type, though both will provide a part of the answer. From a knowledge and understanding of the grasses and trees—especially grasses, it is possible to arrive at a fair estimate of the agricultural potential of almost any area. Manning's recent work in Uganda has shown that where a particular ecological type extends over very large areas minor local differences in rainfall may have a significant effect on crop yields, but in many cases in Kenya ecological zones are so narrow, and the shift of ecological conditions in a very small area may be so great, that the climatological techniques used by Manning may have only a limited application.

Although ecology in Kenya is extremely varied it sometimes occurs in very regular succession, as, for instance, on the slopes of Mount Kenya, where there is a steady progression from a cold wet climate to a hot dry climate. In such conditions it is easy to observe the effect of differing ecology upon the crops grown in the field by Africans, and from these effects it has been possible to assess the potential of any ecological type. The view that it is the natural vegetation which is the key to the whole matter is strengthened by the fact that in the same rainfall range but on a differing soil type, very different vegetation may occur, with corresponding differences in cropping potential.

Examples are where volcanic soil gives way to metamorphic soil or where waterlogging affects the vegetation within the same rainfall range. In general, the effect of gradually decreasing rainfall, both upon the natural grass vegetation and upon cropping potential, is best expressed in the form of a diagram. (*See* p. 68.)

In working out any of these agricultural policies, it has been necessary to start from the following three basic questions:—

1. Do we know of a sound farming system for the area or ecological type concerned?
2. If not, what research is necessary to provide the information on which sound farming methods can be worked out?
3. If there is no available sound farming system, or likely to be, what palliative measures can be applied in the meantime?

Among palliative measures are such things as soil conservation, the use of manure, or the planting of drought-resistant root crops. It is salutary to reflect that these activities, which have occupied so much time and effort in the last decade, are only palliatives and do not solve the essential problem of establishing sound and permanent farming systems.

It should be noted in passing that the systems employed by Africans in Kenya are not considered as sound. In general, Kenya Africans are not good agriculturists; they are

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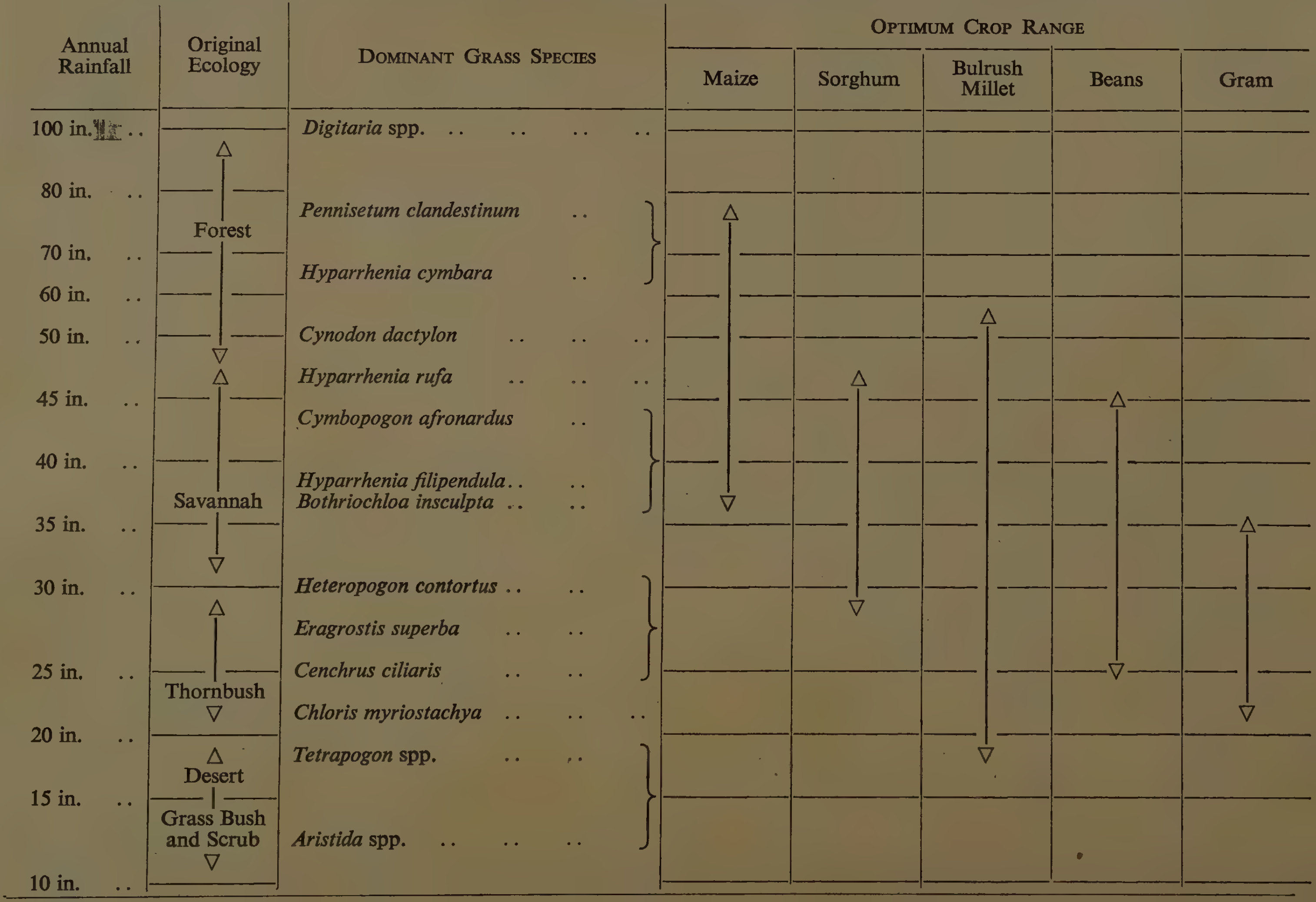
*The substance of this paper was read at the 1956 meeting of the Uganda Agricultural Association.

DIAGRAM I.—RELATION OF RAINFALL—ORIGINAL ECOLOGY—GRASS SPECIES—CROPPING RANGE



for instance, nothing like so able as most West African peasants and in almost any area we feel that we can vastly improve their methods. In fact, if one were to make an objective assessment of existing methods it would be found that probably only about 5 per cent of the total used and inhabited areas of the African land units in Kenya is under beneficial occupation; the rest is being slowly but steadily destroyed, or at best is static, even to-day. In improving this position we will have to make radical changes, but at the same time an endeavour is made to take into account anything of value which Africans may have found out by experience over centuries, and the policy that is aimed at in the end is a synthesis of their needs and their knowledge with our own technical advances and our considerable knowledge derived from research. In much the same way our policy in European farming areas endeavours to take into account the farmers' own desires and interests and to introduce new methods based upon research.

In Kenya we have been fortunate in that we have had research work for many years and it was possible to base our policies, therefore, on a number of already proven principles. In the last five years also there has been an increasingly valuable research organization which has been consistently geared to assist field policy. There is also a tremendous amount of valuable information available through the enterprise of individual farmers, both African and European. One has only to think of the extensive knowledge of the behaviour of different breeds of cattle in Kenya, largely the result of private enterprise, to see that without such enterprise it is unlikely that Government research organizations by themselves would have been able to produce the same volume of knowledge. The value of the results achieved in the last ten years is immense and much that was obscure has now become clear. In general it might be said that results from research work are considerably in advance of general field practice. At the same time, it can be said that nothing that modern research has done has invalidated the ecological approach to the formation of policy.

The result of this mass of knowledge is that in most areas of Kenya we now feel that we are able to advise upon a sound farming system for anybody who wishes to make use of it. Most of the best land in Kenya is in African areas and on this high-potential land we feel able to give sound advice. It is in the marginal areas where some such factor as low rainfall or waterlogging makes ordinary cropping very difficult that we are not so certain about policy. However, even here we are much further on than we were five years ago and we can say that we are in a position to give good advice and that we have a sound policy in most parts of Kenya.

When it comes to putting this policy into force in African areas, however, it is quite another matter. We then find ourselves defeated by social customs and land tenure systems which makes the application of any theoretical policy a physical impossibility. It is therefore clear that to make use of the technical knowledge available these social customs must be modified.

Undoubtedly the worst of all these social customs is the fragmentation of land. In heavily populated districts such as Nyeri, Kiambu or Maragoli, each man's holding is broken up into a number of small pieces. In Nyeri, for instance, the 1950 World Agricultural Census revealed a landowner whose aggregate holding was nine acres, divided up into 29 small plots, the furthest of which was 14 miles from his house. Likewise, in Kiambu, a case is recorded of a man with an aggregate holding of eight acres divided into 43 separate parts, an average of less than one-fifth of an acre per plot. The impossibility of sound farming under these conditions must be evident.

Various benefits are claimed for the system of fragmentation as it exists. Firstly, it is said to divide up different categories of land fairly between every member of a tribe. This argument has force only where a catenary soil formation occurs, as for instance in Sukumaland or parts of Buganda. Even here, however, it could equally be said that optimum land use would probably require specialist farmers producing nothing but rice or sugar or cotton and selling or bartering their products. Secondly, it is said to spread the dangers of catastrophes such as hail or locusts. Probably we do not know enough about the regularity of occurrence of such catastrophes to assess the validity of this argument, but the writer's opinion is that it is much overrated and that the counter-argument of a greatly improved standard of living achieved as a result of consolidation and good farming has far more force.

The disadvantages of fragmentation are far more serious; they include:—

(1) The physical impossibility of adopting elementary sound farming practices. For instance, to manure a plot, a quarter of an acre in extent, three miles away from the homestead on the other side of the valley, requires about 120 man-days' work-time which an average peasant family could not spare even if they would.

(2) It frustrates any attempt at sound rotational practice and compels a tumble-down bush fallow. A man will not plant grass on his plot if he cannot graze it because it is surrounded by other people's cultivation and, as a result, the piece of land is simply left to revert to natural weeds and may, by native custom, be grazed at will by anyone's cattle and goats.

(3) The endless multiplication of jealously maintained boundary furrows renders soil conservation exceedingly difficult.

(4) Time and money are wasted on profitless and bitter litigation.

(5) It is virtually impossible to give sound advice on these fragmented plots. Even if the owner of 29 plots in Nyeri had been willing to accept advice as to what was best to do on each of these scattered plots, it would have taken days of work to visit them all. Had they been in one block, half an hour's work would have produced far more satisfactory results.

(6) Other social evils follow: for instance, if a woman has to walk ten miles to harvest a bunch of bananas, she is unlikely to be able to look after her home as well. Fragmentation plays no small part, indirectly, in such things as the malnutrition of children.

One other point should be made about fragmentation. It may be said that it is an intelligent system whereby land is fairly divided up and catastrophes avoided. The fact is that for whatever reason it was evolved in the first place, it is now an inevitable part of land inheritance systems amongst many tribes. In those parts of the Masai country into which Kikuyu have infiltrated, a typical pattern of Kikuyu fragmentation has developed on land which has only been cultivated for a few years and is virtually virgin. In Embu District the writer has known a plot of two acres in virgin bush split into five on the death of the owner two years later, while fragmentation also occurs among squatter cultivation on farms in the Highlands.

Thus it is that in Kenya the full utilization of technical advice has to wait until this fragmentation problem in certain areas is overcome. There are, however, some areas in which progress can be made without delay. These areas are generally thinly populated as, for instance, Elgon Nyanza, or Kericho Districts. The worst of the problem is that in the densely populated and fragmented areas where there is the greatest need for change, it is most difficult to alter the customs of the people. The main reason for the spectacular progress made in recent years in Kericho District, where there are now approximately 300 square miles of enclosed holdings, is the fact that the land has not already been split up and subdivided as would have been the case in heavily populated Bantu areas.

However, there are certain areas where we can go ahead and where we can look forward to slow progress over a generation or so, and build up a sound farming economy. In Elgon and North Nyanza, for instance, nearly 16,000 acres of land on about 360 holdings have been planned in the last three years and there farm planning is proceeding apace. At the present moment it is too early to say whether it will be entirely successful, since a planned farm demands a great deal of effort and also capital expenditure by the farmer, and if his enthusiasm begins to flag he may abandon the effort. At present it seems that a proportion of these planned farmers will make good. If they do, it is the beginning of an agricultural revolution of far-reaching significance in the whole of Africa.

In planning a farm we always endeavour to provide five basic necessities; they are:—

(1) Homestead area.

(2) An area of permanent and semi-permanent cash crops and famine crops.

(3) An area of arable land adequate for the family's needs and some surplus to set aside against poor years.

(4) An area of temporary and permanent grass equal to or greater than the arable, which provides for keeping stock and for alternate husbandry.

(5) A tree plot.

Wherever possible, an individual water supply is also provided, by a well, a roof catchment, or a communal piping scheme. The proposals are always discussed with the farmer and we try to provide what he wants rather than impose what we think is right for him.

Table I is an example of the economics of a planned farm in summarized form, not in Elgon Nyanza but in the Kikuyu country.

TABLE I—ECONOMICS OF SMALLHOLDING (16.3 acres)

Income	*Sh.*
From surplus food crops (maize, beans, potatoes, bananas, vegetables)	4,323
From cash crops—	
Pine-apples	1,400
Coffee	3,000
From livestock and livestock products—	
Milk sales	5,034
Pigs, sheep, poultry	5,073
Gross income Sh.	18,830

Expenditure	*Sh.*
Labour (four permanent and some casual)	2,700
Repairs, maintenance and implements	600
Spraying livestock and veterinary expenses	700
Feeding-stuffs	990
Seed and fertilizers	400
Transport of produce	990
Depreciation and contingencies	500
Total Sh.	6,390

Net income Sh. 12,451.

Net income per acre Sh. 764.
or £38 4s. per acre net.

It will be seen that from a holding of 16.3 acres the net income is over £600 in one year. This may serve as an example of the sort of benefit which may be derived from a planned farm, though this is a rather favourable case and a particularly able and hard-working farmer.

All farm plans now devised are based upon the Provincial Agricultural Policy which suggests a variety of farming systems which may be employed in any particular ecological zone. Each of these farming systems is designed to produce a full subsistence plus £100 a year income from a holding. The £100 is a purely arbitrary figure, but it is very much higher than the present average income per family, which varies according to district, but is usually under £10 per annum. In most cases it can readily be exceeded by anyone who is sufficiently industrious, and no attempt is made to plan a farm unless the owner is a hard worker and likely to make good. We cannot afford to have too many failures.

Dealing with a fragmented area is very much more difficult, and here we are faced in addition with the urgent problem of improving the standard of living in the shortest possible time. The worse the fragmentation, the more difficult it is to unravel it and, of course, the worse the fragmentation the more acute the general poverty and misery of the inhabitants. Discontent over land is largely the result of fragmentation, and it is not, of course, confined to Kenya.

At the moment, tremendous progress is being made in Kikuyu districts in consolidating fragmented areas. Varying methods are in force, but it is hoped that in three or four years' time fragmentation will be a thing of the past. Nyeri and Kiambu Districts, for instance, aim to complete consolidation in two years, and Fort Hall in five—a total of some 1,200 square miles of high-potential land. Consolidation is also beginning in other areas, particularly in the Luo country of Nyanza Province, but here the problem is even more intractable, since the Luo have a matrilineal system of inheritance and a man can only obtain land from his mother. When we come to tackle this type of fragmented area, we generally find there is an enlightened minority who want to improve their standards of living and are prepared to overcome difficulties to do so. They are, however, opposed by the old men, who have little desire for an improved standard of living and who cannot see why there is any necessity for a change. This conflict is worked upon by political agitators of one sort and another, and before the Emergency in Kikuyu districts these agitators succeeded in a very large measure in preventing much progress towards better farming. The fact that consolidation is now going ahead is due to their absence.

As an example of the benefits which could come from consolidation in a district, let me give details from Nyeri:—

In the years 1952–55, the average income per family from known agricultural exports was Sh. 178, which is a net profit of Sh. 20.7 per acre. Put another way, the total income of the district averaged about £204,000. If the land is all consolidated and is all properly farmed, it should be possible to raise the gross income of the district to about £3,500,000, a net profit of about £18 per acre. It is scarcely necessary to stress the benefits that might result from this enormously greater income available to the populace in terms of social services and education.

In consolidated areas there are always:—

(*a*) People with holdings above average in size and probably beyond their capacity to work efficiently.

(*b*) People with subsistence holdings, with less than the minimum acreage necessary to provide £100 per annum but sufficient to cultivate for food without deterioration of soil fertility.

(*c*) people with very small holdings insufficient to provide their subsistence.

(*d*) Entirely landless people.

Table II is an analysis of three areas in a densely populated part of one Kikuyu district which shows the variation in size of holdings. In this particular area a holding of six acres would be adequate to produce an income of £100 a year and full subsistence, and with industry and the use of fodder crops a still smaller holding could do so. It will be seen that in this particular example there are no absolutely landless people, but that about 20 per cent of the population have holdings too small for subsistence, and that about 25 per cent have holdings larger than a family could efficiently work. It has been shown in high rainfall areas that a peasant family finds it extremely difficult to manage the work on more than six acres unless they are far more industrious than average.

TABLE II

Holding Size (acres)	AREA I		AREA II		AREA III		Av. %
	No.	%	No.	%	No.	%	
0–2	4	2·7	89	34·7	36	20·5	19·6
2–5	38	26·2	82	31·9	69	39·9	32·33
5–8	44	30·4	48	18·6	40	22·4	23·8
Over 8 ..	59	40·7	38	14·8	31	17·6	24·4
Total ..	145		257		176		

It is of interest to note that the landless people are nothing new. Contrary to the general belief held before the Emergency, it has since appeared that there have always been people in Kikuyuland without any land at all. Before consolidation these people had to leave the reserve to find work, but after consolidation they may not have to, for work is available on their doorsteps on the land of the larger farmers. It seems likely that the 25 per cent of farmers in the example given above, with holdings of over eight acres, could easily absorb the surplus labour of those whose holdings are too small for subsistence.

At the present moment, consolidation is pressing on apace in Central Province. The results are sometimes a little alarming. For instance there are in the Fort Hall District narrow strips of land, running from the top of the hill to the bottom, which would horrify a soil conservation purist. In all cases, however, the result can be said to be an improvement on what formerly existed. The woman who has to harvest a bunch of bananas may have to carry it 300 yards up a hill, but at least she does not have to spend the whole day and walk 10 to 15 miles. With consolidation, the man of the house can spend his money on a bicycle or a wireless instead of upon profitless litigation. When one looks at a consolidated area, quite new possibilities seem to emerge, and one can now feel that it is possible to make real progress, and to deal with the land as land on a sensible basis.

Legislation is being prepared to prevent a relapse to the old position and this is also being done in other East African territories. Unless we are hindered by political strife—and this is always the worst danger—we should, within the next decade, be able to bring about very remarkable changes in the agricultural economy in the native areas of Kenya.

It would be wrong to close this hopeful survey without stressing the dangers and difficulties which may result from the changes we are now bringing about. Chief among these is likely to be a very much more rapid population increase. If a man and his wife produce four surviving children, the population doubles in a generation. When there is plenty of money about it may well be that more will be spent upon medical facilities, the infant mortality rate, which is still very high, will be reduced and a much larger proportion of the children born will survive. If this is not accompanied by a reduction in the birthrate, population growth will be excessively rapid and we shall find that in 20 or 30 years' time all the good that is now being done has been undone, and we shall be in the miserable position of India, where, despite several five-year plans, population growth is likely, after a few years, to render the general standard of living in the country no better than it is to-day.

When one looks back to 1946/47 and remembers the hopeless statements that were then made about how every African area in Kenya was grossly over-populated, one can feel with satisfaction that the present picture is a good deal more cheerful. We were told then that it was necessary to move two-thirds of the population of Machakos District into settlement schemes, at vast expense. The only thing that stopped these schemes being launched on this scale was the fact that there was no land for them to go to and no money to pay for them. Nowadays it is not thought that Machakos District, if properly developed, need be regarded as over-populated, and if we can make as much advance in methods over the next ten years, we may grumble about shortage of man power. Problems will undoubtedly arise, but if we look back over the last 10 years we can see that various problems which in 1946 appeared insoluble are now finding their own solution and one may only hope that the same will apply to any new difficulties that develop.

REVIEWS IN BRIEF

PROCESSING OF CASSAVA AND CASSAVA PRODUCTS IN RURAL INDUSTRIES, by L. W. J. Holleman and A. Aten, F.A.O. Agricultural Development Paper No. 54, 1956. Obtainable from the Food and Agriculture Organization, Rome, Italy. Price United States $1.50 or 7s. 6d.

A booklet of 115 pages which describes the cassava plant and its culture, processing of tapioca flour, baked tapioca products, examples of tapioca factories, the analysis of cassava and tapioca, and the uses of tapioca in industries such as textiles, dextrin and glue, laundry and paper manufacture.

MANURING OF TEA IN EAST AFRICA, by R. Child. Pamplet No. 14, Tea Research Institute of East Africa, P.O. Box 91, Kericho, Kenya.

Detailed recommendations for manuring unshaded mature tea in Kenya and Tanganyika, with notes on shaded tea, tea nurseries and tea seed trees.

FERTILIZING FLUE-CURED TOBACCO. Issued in July, 1957 by the Tobacco Research Board of Rhodesia and Nyasaland, P.O. Box 1909, Salisbury, Southern Rhodesia.

Fertilizer recommendations are given for the major soil types in the tobacco-growing areas of Rhodesia and Nyasaland, and there is a brief, but lucid, discussion of the effects of nutrients in plant growth and leaf quality in tobacco.

SUPPLEMENT TO A WORLD DICTIONARY OF BREEDS, TYPES AND VARIETIES OF LIVESTOCK, by I. L. Mason. Supplement to Technical Communication No. 8 of the Commonwealth Bureau of Animal Breeding and Genetics, Edinburgh. Published by the Commonwealth Agricultural Bureaux, Farnham Royal, Bucks, England. 1957. Price 7s. 6d.

Since the first edition of the World Dictionary appeared in 1951, there have been several changes in breed status and in breed names, and some new breeds have been described in the literature. This supplement includes both new entries and replacements for entries in the first edition of the dictionary.

TETRAHEDRON. The International Journal of Organic Chemistry. Vol. I, Part I, 1957. Distributed by I. R. Maxwell and Co. Ltd., 4 and 5, Fitzroy Square, London, W.1, and Pergamon Press Inc., 122, East 55th Street, New York 22, N.Y. Subscription per volume, United States $17 or £6.

The special character claimed for this new journal is its fully international scope, since it is envisaged as a forum for the presentation of original memoirs on organic chemistry contributed from all parts of the world. It is intended to cover all aspects of organic chemistry, whether theoretical or practical, analytic or synthetic, physical or biological. Contributions will be printed in one of three languages, English, French or German.

THE USE OF INSECTICIDES IN FORESTRY AND AGRICULTURE

By G. Watkins, Forest School, Arusha, Tanganyika, and P. T. Walker, Colonial Pesticides Research Unit, Arusha

(*Received for publication on* 11*th April,* 1957)

The need for a short and general guide to the ever-widening field of insecticides was felt to exist for those dealing with the insect pests of living trees and shrubs. The following information was therefore collected with a view to helping foresters and others to select the insecticide best suited to their needs. A brief outline of the classification of insecticides and their properties is given in order to help the prospective user to sort them out and understand their uses. A summary of most of the insecticides at present available is included, but it should be remembered that new names and products are continually appearing, and familiar insecticides often appear under new proprietary names. The concentration of active ingredient is also liable to alter.

Insecticides are frequently employed in forestry against the following insect pests:—

(*a*) Nursery soil pests, especially chafers, cutworms and leather jackets.

(*b*) Nursery stem and foliage pests, especially caterpillars (*Lepidoptera*), locusts and grasshoppers, aphis, weevils, beetles, shoot-borers and gall flies.

(*c*) Stem and foliage pests of larger trees (e.g. arboretum and ornamental trees). Large-scale application by aerial spraying has been practised in other parts of the world, as for example, against the wattle bag-worm in South Africa. The need has not yet arisen, however, to employ foliage insecticides in this territory on a plantation scale.

(*d*) Termites including application on plantation scale.

(*e*) Seed pests, when seed in storage has to be treated to prevent attack by seed-infesting insects.

Apart from certain shoot-borers, suitable insecticides are available against the above pests, but trials may show that even these are susceptible to some of them.

Many highly effective insecticides have been developed during recent years and the field is still expanding rapidly with the continual discovery of new chemicals possessing insecticidal properties.

Insecticides can be classified according to their mode of action or grouped according to their chemical nature or derivation.

Mode of Action

There are firstly, contact insecticides, which cause death after contact with the insect. They may be in the form of droplets which hit the flying or resting insect, or as a deposit on a leaf or bark or in the soil which the insect walks upon, or touches. Stomach insecticides act after being eaten, and are usually avialable as deposits on leaves or bark, or they may be incorporated with an edible material as a bait. Systemic insecticides, eaten or sucked by the insect after passing through the plant tissues on which the insect lives, also act mostly through the stomach. Finally, fumigant insecticides cause death as a vapour.

These modes of action may not be distinct. A fresh deposit of volatile insecticide such as gamma B.H.C. might kill an insect by coming into contact with its feet or mouth parts, by being eaten and absorbed through the stomach or by the vapour entering the spiracles. The terms are widely used, however, and may have some value.

Chemical Nature and Derivation

Chlorinated hydrocarbons, which can be further subdivided into those based on: (*a*) D.D.T., (*b*) B.H.C., (*c*) aldrin, dieldrin and endrin; (*d*) other chlorinated hydrocarbons, such as chlordane, toxaphene, and the new miticides such as P.D.C.B.S.

Organo-phosphorus compounds, such as parathion, malathion and schradan.

Other chemicals, such as lead arsenate, Paris-green, carbon disulphide, and mineral oils.

Plant derivatives such as derris, pyrethrum and nicotine.

CHLORINATED HYDROCARBONS

Interest in the development of the chlorinated hydrocarbons was stimulated during and immediately after the war when many of the conventional poisons were either unobtainable or in short supply. They are usually very complex compounds and are valuable largely as contact insecticides and stomach poisons.

D.D.T. (dichloro-diphenyl-trichloroethane)

In the pure state D.D.T. is a white solid which is practically insoluble in water but soluble in many oils and organic solvents; it is unstable in contact with alkalis, a property it shares with B.H.C. (*see* below). One of its outstanding properties is its prolonged residual toxicity under practical conditions, and this affords a degree of control over a number of insects that has been hitherto unobtainable.

D.D.T. is effective against a wide range of insects including various flies, lice, fleas, beetles and plant bugs although it does not kill all the species belonging to those groups. Some insects have developed a resistance to D.D.T. and this must be overcome by using other chemicals. By adding various chemicals (synergists) to activate the insecticide, it can be made more toxic to some pests.

D.D.T. is virtually non-toxic to man and animals if used carefully at normal insecticidal concentrations. There is a wide margin of safety in its use although it can induce poisoning if abused. The major risk appears to be in its gradual cumulative effects as it is suspected of being responsible for the cause of a number of obscure symptoms in man and domestic animals who have been exposed to it for a number of years. It should not be used on certain crops, especially cucurbits, as it frequently affects their growth, causing chlorosis and stunting.

D.D.T. is formulated for use as an insecticide chiefly in the form of dusts, wettable powders, emulsion concentrates and miscible liquids.

B.H.C. (benzene hexachloride)

Although this was synthesized as long ago as 1825 by Michael Faraday, its insecticidal properties were not recognized until 1941 in France, and independently in England the following year.

There are six isomers or forms of benzene hexachloride, but one, the gamma, also known as lindane, has more marked insecticidal properties than the others.

In the pure state it forms colourless crystals, practically insoluble in water, but soluble in many oils and common organic solvents. It is more volatile than D.D.T. and has a shorter residual duration, but, in general, it is considered more toxic than D.D.T. against a wider range of insects including certain soil pests. One of the disadvantages of crude B.H.C., from the agricultural and horticultural aspects, is that it has a persistent and pungent smell which can impart a bitter taste to various fruits, vegetables and root crops. The pure gamma isomer, however, is virtually odourless and tasteless. B.H.C. can be toxic to man and other mammals if used carelessly, but produces no ill effects if properly applied.

Gamma B.H.C. is perhaps better known as "Gammexane", which is the trade name of one of the manufacturers, Imperial Chemical Industries Limited. For forestry purposes it is used chiefly in the form of dusts, wettable powders and emulsions.

Aldrin and dieldrin

Both these compounds have shown great promise against a very wide range of insects. In chemical structure they are complicated chlorinated hydrocarbons. Originally discovered in the United States in 1948 and first marketed by Shell Chemicals Limited in 1954 as Aldrex and Dieldrex, aldrin and dieldrin are being increasingly incorporated by other firms in their own products.

In pure form aldrin is a nearly odourless white crystalline solid, although the technical material is buff-coloured. It is highly soluble in most organic solvents but insoluble in water.

Dieldrin in the pure form is a light flaked solid, and again the technical material is buff coloured. It resembles aldrin in most of its physical properties, but is less soluble in organic solvents. In contrast to aldrin, it decomposes rapidly in the presence of strong acids, although unlike B.H.C. and D.D.T. neither aldrin nor dieldrin are readily decomposed in the presence of alkalis.

The most important difference between the two materials is that aldrin has a much higher volatility and, consequently, a less marked residual effect than dieldrin. In the soil, however, this higher volatility of aldrin assists in an even distribution and penetration, and if it is incorporated thoroughly into the soil to a depth of three to six inches it can remain effective for a year or more.

Dieldrin is also used as a soil insecticide, but as it is more expensive than aldrin and the difference in their residual effect is only significant above ground, it is usually applied against foliage and shoot insects and not against soil pests in this country.

Aldrin and dieldrin are available for use against forest pests in the form of dusts, wettable powders and as miscible liquids.

Endrin is a more recent development than aldrin and dieldrin, having been first introduced for experimental purposes in 1951. It is an isomer of dieldrin, but has an even greater insecticidal activity than either aldrin or dieldrin against certain foliage pests notably caterpillars.

At present endrin is only available as a miscible liquid, but will probably appear on the market in other formulations later.

There is no marked tainting of crops with aldrin, dieldin or endrin at the usual rates, as is the case with crude B.H.C. Aldrin and dieldrin are more toxic to humans than B.H.C. but experience has shown that there is a considerable margin of safety in their handling if reasonable precautions are taken. Endrin is more toxic than the other two and requires greater care in handling and application.

Other chlorinated hydrocarbons

Many other chlorinated hydrocarbons are known to have insecticidal properties to varying degrees. Perhaps the most important are chlordane and toxaphene, which are persistent and can be used against termites and other soil pests. They are not, however, as widely used as aldrin and B.H.C. for these same pests.

ORGANO-PHOSPHORUS COMPOUNDS

These were developed in Germany during the war and some of them are more highly effective against a wider range of insects than any other chemical now in general use. One of the most efficient is parathion, but it has a very limited use owing to its toxicity to mammals unless applied most carefully. Research is now being undertaken to increase the safety margin of some of these phosphorus compounds and several, such as Diazinon, Dipterex and Malathion, have been produced and are proving themselves successful in the control of aphids, scales and other foliage pests.

The more poisonous members of this group should only be used under supervision and with protective clothing. There is legislation in some territories about their use.

OTHER CHEMICALS

Many chemicals such as lead arsenate, carbon disulphide, carbon tetrachloride, mineral oils and hydrocyanic acid have insecticidal properties either of a contact, stomach or fumigant action. Some of them such as carbon disulphide and Paris-green were standard forest nursery insecticides before the discovery of the more effective chlorinated hydrocarbons.

PLANT DERIVATIVES

Plant materials have furnished some of the most widely used insecticides and the products of such plants as tobacco, pyrethrum, camphor and derris are well known in this respect. Although they still have a place in the control of many insect pests, the future of plant derivatives is rather uncertain. It is likely that, for forestry at least, they may fall into disuse and be replaced entirely by the more recent synthetic insecticides. One of their main disadvantages is that since at least two to four years are required to grow a plant insecticidal crop, their supplies cannot be regulated as quickly and easily as the other types. They also lack the long residual action of many synthetic insecticides.

INSECTICIDAL FORMULATIONS

The various chemical compounds described above are generally too toxic for use as insecticides in their pure and concentrated state. Instead they are diluted or combined with some other chemical or medium so as to facilitate their easy application against different insect pests under diverse conditions. The most common forms in which they are prepared are as follows:—

Dusts.—These are light, free-flowing powders which contain a relatively small amount of the insecticidal substance itself. Most commercial dusts contain from 1 per cent to 10 per cent of active material, with the bulk being some inert filler such as finely ground coral, gypsum, diatomite or talc which acts as a diluent and carrier. Dusts are broadcast dry on to foliage by sprinkling or blowing, special equipment being necessary if on a large field scale. Dusts are equally suitable as soil insecticides by applying them evenly over the soil surface and then incorporating them into the soil to a depth of 3–6 inches. Some concentrated insecticide dusts are also used as seed dressings and for the preparation of cereal baits to control locusts and certain other pests.

If the cost of transport is high, low concentration dusts are the most expensive way of using insecticides, as the proportion of active material to inert filler is very small, and the cost of the latter is included in the cost of the insecticide. The higher concentrate dusts should, therefore, be purchased whenever possible and diluted locally with inert fillers to produce any required concentration. Sand or finely sieved soil make suitable fillers for treatment against soil pests. A commercially formulated dust, however, is probably worth the cost of its use against foliage pests.

Wettable or Dispersible Powders.—These are also powders, sometimes light and free flowing, often similar to dusts in appearance. They contain from about 5 per cent to 50 per cent of active material and so can, in general, be applied in much lower concentrations than dusts.

They are formulated with water soluble compounds, "wetters" or "spreaders", in such a way that the insecticide is held in suspension in water, ready for spraying either as a foliage or soil insecticide. The dispersing agent also helps to "wet" the foliage, so that the spray does not all run off as droplets without depositing any of the active material.

Wettable powders can also be used in the dry powder form for soil treatment, seed dressing, and the preparation of cereal baits. For soil pests it is advisable to dilute the concentrated powder by mixing it with any locally available filler such as fine sand so as to ensure a more thorough distribution when added to the soil. Such diluted wettable powders are also cheaper to use than formulated dusts of a low concentration.

Stock Emulsions (emulsion concentrates).—The insecticide is here already prepared as a concentrated emulsion which only has to be diluted with water for spray application. As the active insecticidal material or a solution of it in solvent is not miscible with water, an emulsifying agent is added to prevent it separating into layers when diluted. It is prepared either as a "flowable" emulsion or as a stiff "mayonnaise" paste. In both of these, the insecticidal material is dissolved in a solvent and intimately mixed with the emulsifying agent and a small amount of water. When prepared for spraying, the stock emulsion concentrate is added to water until the required dilution is obtained.

The stability of these emulsions is variable some of them soon breaking down into layers of water and oil and making the formulation practically worthless as an insecticide. Others are more stable and can remain effective for many years.

Miscible Liquids (liquid concentrates).—These are oily liquids which form an emulsion ready for spraying, on the addition of water. The concentrated liquid consists of an oil solution of the active insecticidal material together with dissolved emulsifying agents.

They are quite fluid and in contrast to the stiff paste type of stock emulsions. When added to water they readily form milky emulsions.

Other Formulations.—Insecticides are also produced in various other forms for use under special circumstances. Some are granular for incorporation with fertilizers or application alone. Others are *volatile liquids* which, after pouring out from their containers, are converted into gases for fumigation purposes, whilst some are even prepared as *capsules* with soluble protective coatings for safe handling of very poisonous insecticides.

TRADE INSECTICIDES

Table I shows tentative dosage rates recommended for the most common trade insecticides now in use against forest and agricultural insect pests. Depending on local conditions, these dosages may need to be modified, and before they are applied on a large scale small trials should be carried out to determine the effectiveness of the insecticide at varying strengths. With reference to insecticides applied by spraying, the dilutions given are intended for high volume (medium nozzle) sprays. For low volume (mist nozzle) sprays, the amount of water can be reduced to about one-quarter of that required for high volume spraying, whilst for medium volume (fine nozzle) sprays, the water quantity can be reduced to approximately one-half of that of high volume. Table II lists most of the forestry and agricultural insecticides sold in East Africa under various trade names. This table will enable alternative insecticides to be selected. Table III lists the common insect pests of trees in Tanganyika.

It is hoped that the information given will be of value to other users of insecticides in East Africa. The position is always changing, however, and as new insecticides and products are continually being developed and research results on them are made known, it is essential that users should get in touch with the trade, its representatives, or Government specialists, in order to keep in touch with the latest information. The respective firms are always willing to provide information on their products, and in some cases issue leaflets, pamphlets and handbooks for particular users.

Acknowledgment is made with thanks to Fisons Pest Control Limited, Plant Protection Limited, and to Shell Chemicals Limited, for permission to quote from private communications and from descriptive leaflets on their proprietary insecticides.

TABLE I

Insecticide	Constitution	Pest	EFFECTIVENESS AND APPLICATION
			Recommended Control
1. DDT 25 Miscible Liquid.	Miscible oil containing 25% DDT.	Leaf-eating weevils, caterpillars, aphis, scales.	3 pints/100 gal. water. Spray direct on to foliage.
2. Dieldrin ..	Miscible oils containing 18% Dieldrin.	Aphis, scales	1 part/20 parts water. Spray base of stem to kill attendant ants (*Pheidole* spp.) which protect the aphis and scales from natural predators and parasites.
		Stem-borers	1 part/35 parts of water.
		Leaf-eating weevils, caterpillars.	1 part/35 parts water. Spray direct on to foliage.
3. Endrin	Miscible oil containing 19·5% Endrin.	Leaf-eating weevils, caterpillars, aphis.	2 pints/100 gal. water. Spray direct on to foliage.
		Cutworms	1 part/45 parts water. Spray on surface of soil.
4. Aldrin	Wettable powder containing 40% Aldrin.	Chafers, cutworms, leather jackets, termites.	Nursery treatment: 4 oz./4 gal. per 100 sq. yd. Spray on to surface of soil and then mix thoroughly to a depth of 3–6 in.
		Termites	Plantation treatment: mix powder with 20 times its volume in sand or fine soil. Mix one cupful of this mixture with soil in planting hole before planting tree.
	1·25% Dust	Soil pests	Dust at 200 lb./acre, hoe in.
5. Malathion ..	Emulsifiable concentrate containing 50% malathion (organophosphorus compound).	Aphis, scales, caterpillars ..	2 pints/100 gal. water. Spray direct on to foliage.
6. Chlordane ..	Miscible oil containing 10% chlordane (chlorinated hydrocarbon).	Chafer, cutworms, leather jackets.	Nursery treatment: 3 pints/100 gal. water. Spray surface of soil and then mix thoroughly to a depth of 3–6 in.
		Termites	Plantation treatment: 2 pints/100 gal. water. Pour 1/5th pint of the dilute solution into the planting hole before planting tree.
		Termite mounds and nests ..	1 pint/25 gal. water. Thoroughly soak nest and spray into air shafts.
		Aphis, scales	3¾ galls./100 galls. water. Spray base of stem to kill attendant ants (*Pheidole* spp.) which protect the aphis and scales from natural predators and parasites.

TABLE I—(*Contd.*)

Insecticide	Constitution	Pest	EFFECTIVENESS AND APPLICATION
			Recommended Control
7. (*a*) BHC dust ..	Dust containing 0·5% gamma BHC and approx. 3·5% other BHC isomers.	Chafer, cutworms, leather jackets, termites.	Nursery treatment: 1 oz./1 sq. yd. Mix in soil to a depth of 3–6 in.
		Termites	Plantation treatment: 1 oz. mixed in with soil of planting hole before planting tree.
7. (*b*) BHC dust ..	Dust containing 6·5% gamma BHC plus other BHC isomers.	Chafers, cutworms, leather jackets, termites.	Nursery treatment: mix 1 oz. powder with 10 oz. sand or fine earth and apply this at rate of 1 oz./1 sq. yd. Mix in soil to a depth of 3–6 in.
		Termites	Plantation treatment: mix 1 oz. powder with 10 oz. of sand or fine earth and mix 1 oz. of this with soil of planting hole before planting tree.
		Seed pests	4 oz./1 bushel of seed. Shake up seed thoroughly with the insecticidal powder.

TABLE II.—TRADE INSECTICIDES

Trade Name	Maker	Formulation: Active Ingredient
A.—THOSE BASED ON BHC (MIXED ISOMERS)		
"Agrocide" 3	Plant Protection Ltd.	Dust: 0·65% gamma BHC.
"Agrocide" 7	Plant Protection Ltd.	Dust: 2·6% gamma BHC.
"Agrocide" 10	Plant Protection Ltd.	Dust: 6·5% gamma BHC.
"Agrocide" 20	Plant Protection Ltd.	Dust: 13% gamma BHC.
"Agrocide" 15 W	Plant Protection Ltd.	W.P.* 10% gamma BHC.
"Agrocide" dispersible powder	Plant Protection Ltd.	W.P.: 6·5% gamma BHC.
"Agrocide" 3:5·0 cotton dust	Plant Protection Ltd.	Dust: 3% gamma BHC, 5% DDT.
"Agrocide" 3:10·0 cotton dust	Plant Protection Ltd.	Dust: 3% gamma BHC, 10% DDT.
"Gammexane" dust (D.034)	Plant Protection Ltd.	Dust: 0·5% gamma BHC.
Dusting powder	Murphy Chemical Co. ..	Dust: 5% BHC.
"Gammatox"	Cooper McDougall & Robertson	Various strengths; dust, wettable powders and emulsion.
"Benhex"	Klipfontein Organic Products ..	Various strengths; dust, wettable powders and emulsion.
B.—THOSE BASED ON GAMMA BHC (LINDANE)		
"Gammalin" 10	Plant Protection Ltd.	M.O.* 10% gamma BHC.
"Gammalin" 20	Plant Protection Ltd.	M.O.: 20% gamma BHC.
"Gammalin" 50 D.P.	Plant Protection Ltd.	W.P.: 50%.
"Gammexane" insect powder (Lindane quality).	Plant Protection Ltd.	Dust: 0·5% and 1% gamma BHC.
"Kynakil" Lindane dust	Plant Protection Ltd.	Dust: 0·04%. gamma BHC.
"Lindex"	Murphy Chemical Co Ltd. ..	M.O.: 20% gamma BHC.
"Lindex"	Murphy Chemical Co. Ltd. ..	W.P.: 25% gamma BHC.
"Lindex"	Murphy Chemical Co. Ltd. ..	Dust: 1% 0·5 and 0·04% gamma BHC.
"Mergamma" A & B	Plant Protection Ltd.	Seed dressings; gamma BHC and fungicide.
"Fernasan" D	Plant Protection Ltd.	Seed dressings; gamma BHC and fungicide.
"Gammalin" seed dressing	Plant Protection Ltd.	Seed dressing; gamma BHC.
BHC Products (Lindane)	Jaygee Products Ltd.	Various strengths; dusts and wettable powders.

* W.P. = Wettable powder. M.O. = Miscible oil.

TABLE II—TRADE INSECTICIDES—(*Contd.*)

Trade Name	Maker	Formulation: Active Ingredient
C.—THOSE BASED ON DDT		
"Arkotine" 18 SD	Shell Chemicals Ltd.	M.O.: 18% DDT.
"Ditreen"	Shell Chemicals Ltd.	W.P.: 50%.
"Didimac" 25 miscible liquid	Plant Protection Ltd.	M.O.: 25%.
"Didimac" 50 dispersible powder	Plant Protection Ltd.	W.P.: 50%.
"Didimac" dusts	Plant Protection Ltd.	Dust: 1%–10% DDT.
"Psylortox" 250	Fisons Pest Control Ltd.	Emulsifiable concentrate: 25% DDT.
"DDT" 33	Fisons Pest Control Ltd.	W.P.: 33·3% DDT.
"DeDeTane"	Murphy Chemical Co.	W.P.: 50% DDT.
"DeDeTane"	Murphy Chemical Co.	M.O.: 15% DDT.
"DeDeTane"	Murphy Chemical Co.	Dust: 5–10% DDT.
"Rentokil" DDT	Rentokil Ltd.	M.O.: 25% DDT.
"Unicrop" DDT	Universal Crop Protection Ltd.	Dust: 5% and 10%.
"DDT" Geigy	Geigy Co. Ltd.	Various formulations.
DDT products	Jaygee Products Ltd.	Various formulations and strengths.
D.—THOSE BASED ON ALDRIN, DIELDRIN AND ENDRIN		
"Aldrin"	Shell Chemicals Ltd.	M.O.: 24% aldrin.
"Aldrex"	Shell Chemicals Ltd.	M.O.: 24% aldrin.
Aldrin 40	Shell Chemicals Ltd.	W.P.: 40% aldrin.
Aldrin dust	Shell Chemicals Ltd.	Dust: 2½% aldrin.
"Alandrin" 40	Plant Protection Ltd.	W.P.: 40% aldrin.
"Alandrin" 2½ dust	Plant Protection Ltd.	Dust: 2½% aldrin.
"Toxadrin" 40	Fisons Pest Control Ltd.	W.P.: 40% aldrin.
Aldrin	Murphy Chemical Co.	W.P.: 40% aldrin.
Aldrin	Murphy Chemical Co.	Dust: 1·25% and 2½% aldrin.
"Dieldrex" 15	Shell Chemicals Ltd.	M.O.: 18% dieldrin.
Dieldrin 50 W.P.	Shell Chemicals Ltd.	W.P.: 50% dieldrin.
"Seedox"	Fisons Pest Control Ltd.	Seed dressing: dieldrin and fungicide.
"Kynadrin" 18	Plant Protection Ltd.	M.O.: 18% dieldrin.
Dieldrin	Murphy Chemical Co.	W.P.: dieldrin.
Dieldrin	Murphy Chemical Co.	Dust: 0·5% dieldrin.
"Endrin"	Shell Chemicals Ltd.	M.O.: 19·5% endrin.
"Maclin"	Plant Protection Ltd.	M.O.: 19·5% endrin.
E.—THOSE BASED ON ORGANO-PHOSPHORUS COMPOUNDS		
"Fosferno" 20	Plant Protection Ltd.	M.O.: 20% parathion.
"Fosferno" 50	Plant Protection Ltd.	M.O.: 50% parathion.
"Pesco" paraphos (pestox 202)	Fisons Pest Control Ltd.	M.O.: 20% and 40% parathion.
T.19	Fisons Pest Control Ltd.	W.P.: 15% parathion.
"Murphos" 35	Murphy Chemical Co.	M.O.: parathion.
"Pesco" Malathion (malalox)	Fisons Pest Control Ltd.	M.O.: 50% malathion.
Malathion P.P.	Plant Protection Ltd.	M.O.: 50% malathion.
"Pestox" 3 (OMPA)	Fisons Pest Control Ltd.	M.O.: 25% Schradan.
"Pestox" 3 (OMPA)	Fisons Pest Control Ltd.	Capsules: 55% Schradan.
"Sytam"	Murphy Chemical Co.	M.O.: Schradan.
"Diazinon"	Geigy Co. Ltd.	M.O.: 60% diazinon (and wettable powder).
F.—THOSE BASED ON OTHER COMPOUNDS		
"Alboleum"	Plant Protection Ltd.	Emulsion concentrate: 80% mineral oil.
"Toxona"	Shell Chemicals Ltd.	Emulsion concentrate: 96·5% mineral oil.
"Triona"	Shell Chemicals Ltd.	Emulsion concentrate: 83·5% mineral oil.
"Arsinette"	Plant Protection Ltd.	W.P.: 97·5% lead arsenate.
"Capex" lead arsenate	Coopers and Nephews Ltd.	W.P.: 97·5% lead arsenate.
"Capex" nicotine dust	Coopers and Nephews Ltd.	Dust: 4% nicotine.
"Clordox"	Fisons Pest Control Ltd.	M.O.: 10% chlordane.
"Murtox"	Murphy Chemical Co.	Emulsion and paste: 50% toxaphene.
"DD" soil fumigant	Shell Chemicals Ltd.	Volatile liquid: 85% ethylene dibromide.
"Pesco" termite fumigant	Fisons Pest Control Ltd.	Volatile liquid.
"Nematox"	Fisons Pest Control Ltd.	Volatile liquid: ethylene dibromide.

TABLE III.—SOME INSECT PESTS OF LIVING TREES

Name of Insect	Species attacked	Nature of Damage	Stage Responsible	Remedial or Preventive Measures
1. *Oemida gahani* ..	*Cupressus* spp. Cedar (*Juniperus procera*).	Heart wood of large trees tunnelled and converted to powder.	Larvae ..	Early pruning. Avoidance of scars on bark.
2. *Androeme plagiata*	*Cupressus* spp. and various hardwoods.	Heart wood of large trees tunnelled and converted to powder.	Larvae ..	Early pruning. Avoidance of scars on bark.
3. Cutworm	Most spp.	Young seedling cut through at root collar.	Larvae ..	*See* aldrin, chlordane, BHC, Table I.
4. Leather jackets ..	Most spp.	Roots of young seedlings eaten.	Larvae ..	*See* Insecticides, aldrin, chlordane, BHC, Table I.
5. Chafers	Most spp.	Roots of young seedlings eaten.	Larvae ..	*See* Insecticides, aldrin, chlordane, BHC, Table I.
6. Eucalyptus Snout Weevil (*Gonipterus scutellatus*).	*Eucalyptus* spp. esp. *maidenii* and *globulus*	Defoliation (Kenya and Uganda only).	Larvae and Adults.	Plant resistant Euc. spp. *saligna*, *citrodora*, *paniculata*. *See* also Insecticides.
7. Locusts and Grasshoppers.	Most spp.	Defoliation	Adults and Nymphs.	*See* Insecticides aldrin, dieldrin, BHC, Table I.
8. Caterpillars (*Lepidoptera*).	Most spp.	Defoliation	Larvae ..	*See* Insecticides, DDT, endrin, Table I.
9. Shoot-borers. (*Cerambycidae* or Longicorns) and *Cossidae* (*Lepidoptera*).	Mahogany, *Markhamia* Camphors, other hardwoods.	Young shoots killed by tunnelling.	Larvae ..	Hand-pick and burn infested shoots. *See* also Dieldrin, Table I.
10. Mvule gall fly. *Phytolymaleta*.	*Chlorophora excelsa* (Mvule).	Galls on leaves and shoots of young trees.	Nymphs ..	*Plant under light shade and in favourable sites. Slice galls open every week.
11. Aphis (*Aphididae*) ..	Various hardwoods ..	Sucking of sap from young shoots and foliage.	Adults and Nymphs.	*See* Insecticides BHC, Malathion, DDT, Table I.
12. Scale Insects (*Coccidae*).	Black Wattle, Teak and various other hardwoods.	Cover stem and branches. Reduction in general vigour of the tree.	Adults and Nymphs.	*See* Insecticides Malathion. Table I.
13. Termites—white ants	Various hardwoods and conifers.	Roots collar girdled, killing tree.	Adults ..	Dig out queen and destroy mounds. *See* also Insecticides Aldrin, Dieldrin, BHC.
14. Bark Beetles (*Scolytidae*).	Most spp.	Pattern of tunnels under bark and on wood surface. Not entering wood to any extent.	Adults and Larvae.	Not known.

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*Dieldrin has recently proved effective.

A POSSIBLE CASE OF COFFEE THRIPS RESISTANT TO D.D.T.

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(Received for publication on 25th April, 1957)

SUMMARY

D.D.T. has controlled the common coffee thrips, *Diarthrothrips coffeae* Williams, in Tanganyika for about seven years, but during 1956 the insecticide failed completely to check the rise in populations at Oldeani while it continued to be satisfactory on Kilimanjaro. An investigation suggests that the Oldeani strain of thrips has built up a resistance to D.D.T., but there is an indication that another factor, vigour tolerance, may be involved.

D.D.T. was first used to control the common coffee thrips, *Diarthrothrips coffeae* Williams, in 1948 (Notley, 1948) and while no figures are available the results appeared to be satisfactory. It was used again in 1949 on the Coffee Research Station (Notley, 1949). No other investigational work was carried out, but farmers have used D.D.T. at the rate of ¾ lb. to 1 lb., per acre for several years with very satisfactory results, until a report of its failure came from Oldeani in the Northern Province of Tanganyika, in 1956. The farmer stated that the usual thrips control measure gave absolutely no control and that populations continued to increase. A double strength emulsion was used, and even though some trees were thoroughly saturated, gave equally ineffective results.

At the end of November when most thrips infested areas were completely defoliated a small non-statistical trial was laid out in a few remaining foliated trees. Rows of coffee, each containing eight trees, were sprayed and each treatment was separated from other treatments by a single guard row. Thus the whole experiment was contained in about quarter of an acre.

Table I gives details of treatments and results. Each tree was sprayed with half a gallon of insecticide, an excessive amount, to ensure that all leaves were thoroughly covered.

A count made in the plot before treatment revealed a population of 808 thrips per 100 leaves, and this took no account of the insects on the buds and stems.

All counts were based on the method described by Le Pelley (1942), and in each count 100 leaves were sampled.

A quantitative analysis of D.D.T. on treated leaves after eight days' exposure in the field was made by the Colonial Pesticides Research Unit, Arusha, and the results are contained in Table II.

The usual deposit of D.D.T. on coffee leaves sprayed at the rate of 13 ounces of actual D.D.T. per acre in high volumes of water is about 2.2 mgm. per square foot and after eight days' exposure about 0.86 mgm. per square foot (Sleep, K., 1957).

TABLE I—SHOWING TREATMENTS AND THRIPS POPULATIONS ONE DAY, THREE DAYS AND EIGHT DAYS AFTER SPRAYING

INSECTICIDE AND CONCENTRATION	NUMBER OF THRIPS PER 100 LEAVES AFTER:					
	24 hrs.		3 days		8 days	
	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs
D.D.T. 0·1 % emulsion, "A" formulation ..	9	22	70	181	263	239
D.D.T. 0·1 % emulsion, "B" formulation ..	7	16	33	184	267	186
D.D.T. 0·2 % emulsion, "A" formulation ..	17	21	73	127	291	158
D.D.T. 0·4 % emulsion, "A" formulation ..	10	6	3	8	70	10
Chlorothion 0·1 % wettable powder ..	3	6	7	4	98	63
Parathion 0·05 % emulsion	4	4	3	2	30	12
Dieldrin 0·05 % emulsion	7	2	2	0	10	51
Control	not counted estimated total >500		60	297	225	450

During the same period at the Coffee Research Station, near Moshi, a 0.1 per cent D.D.T. emulsion reduced the same species of thrips from 121 per 100 leaves to 27 after the first day, and two thrips per 100 leaves on the third. The population rose to three on the seventh day, 17 after two weeks and 32 per 100 leaves after one month. The numbers of thrips remained below the danger point for one month after treatment although the weather, according to Notley (1940), was suitable for a rapid rise in populations; i.e. the average maximum daily air temperature comfortably exceeded 27° C. The coffee was not irrigated during this period.

Following the experiment the estate at Oldeani was sprayed with a 0.05 per cent dieldrin emulsion with satisfactory results. Spraying at this stage could not save old leaf, but prevented damage to a new flush of leaf following rain.

DISCUSSION AND CONCLUSION

In the Oldeani strain a study of the nymphal figures probably gives a truer picture of the effect of the insecticide than adult figures, as nymphs can be expected to live near to the place where they were hatched, whereas adults may fly in from untreated trees. It is evident that all insecticides reduce thrips populations initially, either as a chemical or mechanical effect, but the newly hatching nymphs on the 0.1 per cent and 0.2 per cent D.D.T. treated trees did not appreciably succumb to the residual insecticide, while they were destroyed on the 0.4 per cent treated trees which held a comparatively massive dose, even after eight days' weathering. Adult thrips seem to be equally unaffected by the D.D.T. on the 0.1 per cent and 0.2 per cent trees, and even the 0.4 per cent D.D.T. trees carried a considerable number after eight days.

The thrips were susceptible to low doses of chlorothion, parathion and dieldrin. Chlorothion and parathion are considered to be relatively non-persistent and this may account for the rise in populations after the eighth day. Dieldrin, on the other hand, probably has a similar level of persistence in the field to D.D.T., and the rise in the number of nymphs on the eighth day is interesting since insects which have become resistant to D.D.T. do not usually show any immediate resistance to the aldrin and dieldrin group of compounds. This suggests that, by virtue of the conditions under which they exist, including repeated exposure to D.D.T., the thrips acquired a degree of toughness which renders them more tolerant of insecticides in general. This concept is referred to as "vigour tolerance", and is different from "insecticide resistance" where a definite mechanism has been developed to combat one or more groups of insecticides (Hoskins and Gordon, 1956).

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TABLE II—SHOWING DEPOSIT OF D.D.T. ON SURFACE LEAVES AFTER EIGHT DAYS' EXPOSURE IN THE FIELD

Leaves treated with D.D.T. at	0·1%	0·2%	0·4%
Amount of D.D.T. on surface of leaf	0·3 mgm. sq. ft.	0·3 mgm. sq. ft.	6·1 mgm. sq. ft.
Amount of D.D.T. absorbed by leaf	0·4 mgm. sq. ft.	0·8 mgm. sq. ft.	0·8 mgm. sq. ft.
Total D.D.T. leaf	0·7 mgm. sq. ft.	1·1 mgm. sq. ft.	6·9 mgm. sq. ft.

RECLAMATION AND PASTURE MANAGEMENT IN THE SEMI-ARID AREAS OF KITUI DISTRICT, KENYA

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(*Received for publication on 6th April, 1957*)

This Paper is intended to describe a practical approach to some agrarian problems which have been encountered, and in some measure overcome, in this district during the last four years.

The position in Kitui in early 1953 was that there were vast areas of completely denuded pasture lands—estimated at some 80,000 acres—scattered throughout the length and breadth of the district, generally adjacent to, or on the approaches to permanent water. All such areas were in an advanced state of sheet erosion, with gullying in varying degrees. There were other areas—estimated at 800 square miles—which had almost completely lost their cover of perennial grasses, leaving only poor annuals and many species of herbs. The tree/bush cover varied from stunted *Commiphora* and *Acacia* spp. through a variety of thickets—mainly *Commiphora*—to widely spaced flat-topped Commiphoras. There was little, if any, gullying on these areas, but the visual signs pointed to over-grazing, and it can be assumed that only lack of permanent water prevented further deterioration.

Most of the pasture and grazing areas in the district are communal, and are grazed on a communal basis. Large areas of communal grazing were and still are predominantly bush.

A stock census in 1949 showed that the district was carrying 306,000 head of cattle, 741,000 sheep and goats and 3,100 donkeys. Rainfall during 1948 was exceptionally good and the rainfall figures for 1949 were also above average. By 1953 the stock population had decreased somewhat through natural agencies—thirst and starvation. The failure of the March/April rains of 1953 accounted for 30,000 to 40,000 head, the majority of which died in the dry eastern locations of the district. The mortality was also high during 1954 and 1955. The annual calf crops have compensated for the losses to a large extent and it is believed that the average cattle population has stood at around 300,000 head for the past several years.

In these conditions the district was clearly carrying more stock than it had grass for. Survival of cattle was more a matter of good luck than good management, and undoubtedly browse helped to keep the stock population at above optimum. Permanent water supplies were few and far between, and situated mainly in the seven permanent rivers which, with their lesser tributaries, cover the native land unit, 6,384 square miles in extent. A dozen boreholes, several large dams and several hundred small dams (not permanent) helped to fill in the gaps.

This then was the position in early 1953, and it was on these known facts that a pasture and livestock policy had to be based.

The reclamation of the bare eroded areas presented no great technical difficulties. It was known—through experiments carried out by L. H. Brown, in Embu District—that scratch ploughing on the contour followed by seeding and closure could produce a grass cover more or less compatible with the quantity and type of seed sown. The difficulty lay in maintaining that cover, a problem more administrative than technical in nature. The first questions to arise therefore in the formulation of a policy were control and regulation of stock numbers and better use of available pastures.

These two points are of paramount importance in the formulation of a stock policy; they were not, however, considered to be a prerequisite to the general reclamation programme and it was felt that it was necessary first to win the confidence of the people by actual demonstration. The final policy was laid down in the following order of priorities:—

(i) Reclamation of the bare eroded areas.

(ii) Acceleration of establishment of perennial grasses.

(iii) Bush clearing on communal grazing areas.

(iv) Control grazing.

(v) Limitation of stock to carrying capacity.

(vi) Improvement of water supplies for livestock.

(vii) Improvement of livestock.

(viii) Comprehensive cattle counts.

The vegetation and treatments applied to items (i), (ii) and (iii) were as follows:—

RECLAMATION OF BARE ERODED AREAS

The bare eroded areas were generally found on red sandy loam, at altitudes between 4,000 and 1,500 feet with an average annual rainfall of between 7 and 26 inches. They were predominantly bare areas of sheet erosion with gullying in varying degrees, with a vegetative cover of stunted *Commiphora* and *Acacia* species, few or no perennial grasses and small islands of *Eragrostis cilianensis, Eragrostis aethiopica, Aristida adscensionis, Tetrapogon spathaceus* and *Latipes senegalensis* growing under protection of scrub and bush where cattle could not eat them. Reclamation of such an area demanded complete closure from animals during the period of recovery, and a brush fence cut from the area was found quite adequate for this purpose.

In the reclamation process all *Commiphora* species and useless bush were felled, the area was roughly ploughed at three-feet intervals on the contour, and the plough scratches were sown to perennial grasses. It has been found that the establishment of pioneer grasses is not necessary under these conditions and the seed is usually a mixture of such perennials as *Chloris myriostachya* and *Eragrostis superba*, with sometimes a small percentage of *Cenchrus ciliaris* or other useful species. The seed is sown before the rains are due, and during the rains Star Grass (*Cynodon* sp.) is planted at wide intervals. Any surplus bush is spread over the bare areas, giving some protection from sun and small game.

Grass seed is harvested throughout the district during the months February/March and June/July. It is dried, treated with 1 per cent D.D.T. dust or Agrocide 3 as a preventative against loss by harvester ants when sown, and stored in bags for sowing prior to the rains. It is advisable to keep seed stored for 12 months before sowing as viability tends to increase. Viability probably decreases again after this period, but this point has not been proved by controlled trials. Using this scratch ploughing and reseeeding method, given favourable weather conditions, up to 80 per cent grass cover is established in 18 months after sowing and full cover in two years.

It has been found necessary to burn these areas as soon after a full cover of combustible material has been obtained as will give the best results. This is usually in the month of October, just before the onset of the main rains in Kitui, and is to control the regenerated bush and excessive growth of useless herbs, and generally to clean up the area. The chief requirement is a maximum amount of combustible material; it is not advisable, therefore, to graze the area before burning. The exception to the above is in the rare instances where there is no regeneration of bush; generally the more denuded an area the less regeneration will take place.

It has been found, through trial and error, that gully control is better done after a good grass cover is established; otherwise the gully control measures are likely to be washed out during heavy rain by the run-off from bare ground.

ACCELERATION OF ESTABLISHMENT OF PERENNIAL GRASSES

The establishment of perennial grasses on the areas where these grasses were lacking presented a similar set of problems to those on the bare areas of sheet erosion. The areas concerned lie chiefly between 2,000 and 4,000 feet A.S.L., on red sandy loam with an average annual rainfall of 15 inches to 26 inches. The arboreal vegetation is made up of widely spaced flat-topped *Commiphora* species, *Acacia* spp. and an occasional *Balanites aegyptiaca* at the higher altitudes. Grasses include *Eragrostis cilianensis, Eragrostis aethiopica, Dactyloctenium aegyptium, Chloris virgata, Aristida ascensionis, Setaria pallidifusca* and *Latipes senegalensis,* plus a variety of herbs, the whole giving a fairly good ground cover. There is little, if any, gullying in these areas. Treatment is the same in principle as in the bare areas, but in order to cover as large an area as possible the plough scratches are made at 10–12 feet intervals and seeded to perennial grasses, *Chloris myriostachya* and *Eragrostis superba.* After the ploughing and seeding operations have been completed, *Commiphora* and all other useless bush is felled and left to rot on the ground. (There may be objections to this in tsetse fly areas due to the breeding habits of *G. longipennis.*)

These areas are burned as soon as there is sufficient combustible material available to ensure a good burn; this is not so much for the control of regenerated bush as for the destruction of useless herbage and the general cleaning up of the felled bush. In such areas grazing control in itself tends to increase the perennial stand of grasses, but the ploughing and seeding operation greatly accelerates their establishment.

CONTROL OF USELESS BUSH IN COMMUNAL GRAZING AREAS

Vast areas of the district are predominantly bush, on both black and red sandy loams at altitudes varying from 3,700 feet to 1,500 feet, with an annual average rainfall of 15 inches to 30 inches.

Bush clearing in itself presents no difficulties and is merely a matter of cutting down the bush to as near ground level as possible, leaving only large *Acacias* and other trees for shade. The bush is scattered rather than stacked in heaps or hedgerows, the problem being to prevent regeneration. Several experiments have been carried out, all of which include fire as a necessary medium to control regeneration of bush. Control areas which have not been burnt are regenerating bush rapidly.

In most of the experiments the grass was burnt 18 to 24 months after bush cutting, and just prior to the main rains in October. At this period, most of the areas had sufficient combustible material, with low and vunerable regenerated bush, which ensured a successful burn. Given favourable weather conditions it is possible to burn the area with advantage 12 to 18 months after the bush has been slashed or cut. The ecological complex in one particular area treated at an altitude of 3,400 feet with an average rainfall of 20 inches (about 590 acres) has been transformed from *Acacia pennata* dominant to 60 per cent *Chloris myriostachya*, 20 per cent *Eragrostis superba*, 15 per cent other species and 5 per cent bare areas. The 15 per cent other species includes *Panicum maximum*, *Chloris virgata*, traces of *Themeda triandra* and some lesser herbage. The bare areas were caused by excessive heat, which is undesirable except to kill stumps, heaps and hedgerows.

Areas cleared from bush have not been artificially seeded and the rapid appearance of perennials on them suggest that the greater portion of the Kitui Land Unit is potentially perennial grassland. It would appear also that the balance between grass and bush is delicate; on the other hand it is also evident that these areas do respond favourably to treatment and management and this brings us to items (iv) and (v) of the stock and pasture policy. As mentioned earlier, these two points are of paramount importance if the efforts and labour put into items (i), (ii) and (iii) are not to be wasted. It was realized at the outset that to implement these two points with success, the trust and good will of the people would first have to be established. This was achieved by demonstration, tours of reclaimed areas, slide shows and other propaganda. The fact that thousands of head of cattle died from thirst and starvation provided the logic for argument in favour of grazing control and stock limitation, and it did not take long to obtain the co-operation of the stockowner.

GRAZING CONTROL

Prior to 1954 there was virtually no controlled grazing in the district. Cattle grazed as close to home as water or grass would let them, causing much unnecessary trampling and damage to pasture. Few areas of grass had any rest period or time to seed and good grasses were eaten out almost as soon as they appeared.

Grazing control was started in three of the more progressive locations in early 1954. By late 1955 more than half of the district had some sort of grazing control, and at the time of writing—February, 1957—all communal grazing areas are under controlled grazing. The area involved is some 6,300 square miles inhabited by 250,000 people.

The forms of control vary of necessity to fit in with water availability, and generally the grazing areas are divided into three main groups:—

A—Areas where water is only available during and for a short period after the rains.

B—Areas where there is water during and for several months after the rains; these areas contain small dams, water-holes and temporary streams.

C—Where there are permanent rivers, permanent dams, boreholes and piped water supplies.

These main areas, A, B. and C, are subdivided into grazing camps which are grazed off in rotation. If a camp is reserved for burning for bush control it is closed to grazing for 12 months before the burn is scheduled to take place.

The stage has not yet been reached where time-table methods of control are feasible, as to apply such a system it would first be necessary to know exactly how many cattle are grazing in each area, and the carrying capacity of each camp would have to be assessed—a formidable task, where an area of 6,340 square miles has to be covered. What is done—and it is quite effective—is to graze all the cattle from a given area or location in one camp, in an A area if there is water, in a B area when the water in the A areas is finished, and when there is no water in either the A or B areas, in the C areas on the permanent water. The cattle stay in that camp until they have cropped the grass down to a few inches and they are then transferred to the next camp, and so on. In this manner there is always a reserve of standing hay adjacent to permanent water for the really dry months, September/October. This system is simple enough for the African field staff and the stockowner on whom practical control in the field depends, to understand, and it works quite well, which is the main thing. The camps are so arranged that it is hardly possible for one camp to be grazed at the same time during two successive years. More permanent systems of grazing control will be started on some areas which now have good water distribution when a stock count, which is at present in progress, has been completed.

Evaluations of grass cover on areas which have been under such grazing management for 18 months or more, show a definite increase in favour of perennial grasses.

Limitation of Stock to Carrying Capacity

The 1949 stock census showed that there were over 700,000 sheep and goats in the district, and it is estimated that there are now considerably more. Hides and skins figures show that goats outnumber sheep by 6:1. Sheep are so few in numbers that they are not given special attention. Goats have been much maligned in the past and on this account, coupled with the fact that they outnumber cattle by 2:1, they have been the subject of careful scrutiny and study. It has been found that, given the choice of pasture and browse, a goat invariably takes the browse. They are inclined to make tracks through bush and grass, but this appears to be their only bad habit. They are often seen on bare eroded areas, presumably because they are the only animals that can live there, and it is unjustifiable to assume that these areas of denudation were created by goats. They could be quite useful in the control of regenerated bush and this is the subject of future experiments.

The first move to implement stock limitation (apart from the propaganda) was to improve buying and selling facilities for the stockowner and the itinerant cattle trader alike. In 1954 there were only two cattle sale rings in the district. These were increased to 10 and a further two are projected. Twenty-two holding grounds of adequate size have also been provided, which makes the movement of sales stock much easier for beast and herdsman. With these provisions the district now has adequate marketing arrangements.

Secondly an off-take quota, based on grazing availability, was compiled and a programme of auctions made out. Location councils handled the details of the off-take from each location, while the Veterinary Department were responsible for organizing sales and sale rings. The number of cattle that passed through the sale rings in 1954 was 3,334 head, in 1955 24,239 head were sold, and in 1956 sales amounted to 30,733 head.

In addition to this decrease in the cattle population at least 24,000 head died of thirst and starvation during 1955. There were virtually no deaths from thirst or starvation during 1956, and the position now is that the cattle population is at or slightly below optimum.

Improvement of Water Supplies for Livestock

At this stage of development this is an important aspect of the general stock policy and is covered by the formation of "The Kitui Water Supplies Organization". It includes three five-ton Bedford diesel lorries, one stone crusher, two concrete mixers, a compressor, tools and technicians. In an area such as Kitui where natural water supplies are scarce ingenuity must be used to make the most of them. Methods employed have included boreholes, earth dams, sub-surface dams in sand river beds, rock catchment dams (one of which collects the water from 460 acres of bare rock), piping of tapering streams and springs, and pipelines with pumps from large dams and sub-surface dams. Much of this work is paid for by the people themselves by means of a water development rate.

Improvement of Livestock

This is a projected scheme, instigated by the Veterinary Department, which will allow for something in the region of 900 selected heifers from the land unit to run with improved bulls on the B2 Yatta Grazing Scheme. The annual turnover of improved calves that come back into the district may eventually be in the region of 400 and should go far towards improving the type of animal offered for sale in future years.

COMPREHENSIVE CATTLE COUNTS

This item comes last on the list, but is by no means least important, as, without such counts it would be difficult, if not impossible, to hold the grass/stock balance at its optimum. Ideally the cattle count should be an annual event, assuming that the carrying capacity of the district is going to increase through better management from now on rather than remain static.

The first comprehensive stock count—since the 1949 stock census—is now well under way and is scheduled to be completed by the end of March, 1957. The figures obtained from this count will provide the basis for calculating the off-take of cattle from the district for the period May, 1957–April, 1958. The count was arranged as a result of a request from the Kitui African District Council at their December, 1956, meeting and is being organized by the Veterinary Department.

The continued success of this livestock policy now depends almost entirely on marketing facilities, which implies a regular consumer demand outside the district, and the aim is to try to produce as high quality an article as is possible.

In conclusion I would emphasize the following points:—

(*a*) The grass/bush balance is delicate and management is necessary to tip the balance in favour of grass.

(*b*) It is evident from experience that regeneration of bush can be kept in check by intelligent pasture management which includes a periodic burn in the rotation.

(*c*) Trials and observations show clearly that controlled grazing can and does increase the proportion of perennials to annual grasses and there is no doubt whatever that this aspect of pasture management pays the biggest dividends.

(*d*) It is possible (technically) to transform vast areas of bush and scrub to a savannah/shade tree ecological complex, and keep them in that condition.

(*e*) Closure alone of the bare eroded areas, with no other treatment, requires a recovery period of six to eight years as compared to two to three years (or less) when scratch ploughed and seeded.

The above notes refer only to reclamation and pasture management within the native land unit of Kitui District. They do not apply to the eastern Crown lands of the district where low rainfall, high temperatures, lack of water and termites, present special problems which I will not go into here. Nor do they apply to the Athi Tiva Scheme, which—although it is within the native land unit—is primarily a scheme to eradicate tsetse fly, and in which erosion and reclamation is not a problem, though the lessons learned about control of bush in Kitui District will be useful.

THE EFFECT OF RING-BARKING AND 2,4,5-T APPLIED AS A BARK PAINT ON ACACIA SEYAL DEL

By **J. D. Lea, Research Division, Sudan Ministry of Agriculture***

(*Received for publication on 30th April, 1957*)

In the Sudan much of the clay plain lying between the Blue and White Niles south of the 25-in. isohyet is covered by an *Acacia seyal* woodland. As several hitherto undeveloped areas of this woodland, especially those alongside the railway line running from Sennar to Roseires, may prove suitable for mechanized rain-fed agriculture, or for irrigation from the Blue Nile, preliminary work on clearing *Acacia seyal* by ring-barking and with 2,4,5-T applied as a bark paint was started at Central Rainlands Research Station, Tozi, in late 1953. Normally on new schemes in this area woodland is cleared and stumped by hand. The contract charge for this in fairly thick woodland is around £8 an acre, and it was thought that ring-barking or chemical treatment might reduce this cost. In addition to the work recorded here trials on clearing the woodland mechanically were started at Tozi in the 1955/56 dry season.

DESCRIPTION OF THE WOODLAND

Typically, the woodland consists of a uniform stand of *Acacia seyal* with a ground flora composed almost entirely of annual herbs, the grasses (mainly *Sorghum purpureo-sericeum*, *Beckeropsis nubica*, *Rottboellia exaltata*, and *Hyparrhenia pseudo-cymbaria*) growing six to ten feet high. Other less important trees are scattered *Balanites aegyptiaca; Acacia fistula*, generally most common in broad shallow depressions; *Acacia senegal;* and *Acacia campylacantha*, which in the Tozi area is a small tree up to ten feet high. It often has many stems and is consequently difficult to ring. In the Sudan *Acacia campylacantha* attains its characteristic stature and growth form only in the more southerly regions. The woodland is sometimes associated with patches of open treeless grassland, but these areas are limited in extent in the *Acacia seyal* zone.

Except in areas reserved for *harig*† cultivation the grass is almost invariably set alight during the seven-month dry season. Contrary to expectation grassland regularly burnt does not always burn uniformly and unburnt patches frequently are left. Grassland protected for a season or two gives a more complete burn because of an accumulation of dead grass on the ground.

FIELD TRIALS

In October, 1953, a comparison was made of ring-barking and treatment with 2,4,5-T n-butyl ester. The plots, each of 2.5 acres, contained an even stand of *Acacia seyal* with a few *Acacia campylacantha, Acacia senegal* and *Acacia fistula*. The 2,4,5-T was made up in diesel oil at a concentration of 2 per cent acid equivalent (500 c.c. 2,4,5-T in 9,500 c.c. diesel oil; equivalent to 20 lb. 2,4,5-T acid in 100 gal. diesel oil), and applied with a brush to a ring of bark 1 ft. wide at a height of about 4 ft. In the ring-barking treatment a similar strip of bark was cleaned from the trunk at the same height. The bark on the painted portion of the trunk dried out to a certain extent, and in some cases gum globules formed at horizontal cracks and at branch scars. Gum also formed in quantity around the ring-barked section and the plot was soon well stripped by local gum collectors.

The results, presented in Table I, were assessed in January, 1955, when the number of living and dead trees was counted.

TABLE I—EFFECT OF RING-BARKING AND OF A 2 PER CENT ACID-EQUIVALENT SOLUTION OF 2,4,5-T APPLIED IN DIESEL OIL AS A BARK PAINT ON *Acacia Seyal* TOZI, 1953–55

	No. of Trees per Feddan‡			
	Total		Per cent	
	Dead	Living	Dead	Living
Ring barked ..	152	31	83	17
2, 4, 5–T ..	26	209	11	89

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* Present address: Cotton Research Station, Namulonge, Uganda.

† A system of crop production in which early weed growth is killed by burning off, after the start of the rains, a mat of dead grass accumulated over two to three years by protection from dry season fires.

‡ One feddan ≃ approximately one acre.

The ring-barking killed 83 per cent of the trees, while 11 per cent only in the 2,4,5-T plot were killed. The living trees in the ring-barked plot had, in very nearly every case, produced a narrow strip of bark which bridged the section originally cleaned of bark. The living trees were cut down by hand after the count in January, 1955. By the end of 1955 (after another rainy season) over 60 per cent of the dead trees had either fallen or been blown over, and many trees contained wood-borers which made it easier to push the dead trees down. There was no marked tree regeneration from seed, stumps or roots in the ring-barked plot at two years from treatment.

Midway through the 1954/55 dry season a square kilometre block of woodland containing mainly *Acacia seyal* and *Acacia fistula* with scattered *Balanites aegyptiaca* was ring-barked. This time the bark was removed from ground level to a height of 3 ft., and care was taken not to leave any thin strands of bark running across the cut section. The cost of this work was 31 pt./feddan (about Sh. 6 per acre). By November, 1956, a little over 90 per cent of the *Acacia seyal* and *Acacia fistula* trees were dead. Of these about 50 per cent had fallen down. *Balanites aegyptiaca* was not apparently affected by ring-barking, though this treatment killed a single tree of this species ring-barked in the smaller plot in 1953.

Although both the small and the large plots were fire-lined with the intention of protecting the grass from fires for one complete dry season so as to obtain a dense mat of grass that would burn strongly enough to set the dead trees alight, accidental fires ran through them each dry season. Although the fallen trees burnt out satisfactorily, in most cases down through the stump as well, the standing trees did not catch alight. To obtain a more complete burn it would be necessary to knock down the standing trees before firing the grass.

DISCUSSION

It appears from the two trials at Tozi that the best procedure to follow when clearing *Acacia seyal* woodland by the ring-barking method would be to ring during the dry season, and then burn in the second dry season from treatment. In this second dry season some (not more than 50 per cent) dead trees and possibly a small percentage of living trees (less than 10 per cent) will still be standing, but these could almost certainly be knocked down quickly and at low cost by a tractor-drawn chain, or with a hand-winch. Alternatively it may be more satisfactory to let the area lie for a third season, to decrease the number of standing trees to be dealt with.

Ring-barking clearly shows promise as a cheap method of clearing *Acacia seyal* woodland, but further work on preparing the land for cultivation after the final burn is required before the method can be recommended as completely satisfactory. The *Acacia seyal* gum formed after ring-barking though of poorer quality than *Acacia senegal* gum (gum arabic) would provide a small additional source of income to the farmer, and the dead timber would, of course, provide firewood and charcoal.

SUMMARY

Acacia seyal, which grows in an almost pure stand over much of the Sudan clay plain in the 25–35-in. rainfall zone was effectively killed (83–90 per cent) in two trials at Tozi by ring-barking a section of the trunk. A 2 per cent solution of 2,4,5-T (20 lb. 2,4,5-T acid in 100 gal. diesel oil) was much less effective and gave only an 11 per cent kill. In the second dry season from treatment about 50 per cent of the dead trees had fallen down. At this time there was no marked regeneration from seed, stumps or roots. When the grass was set alight the fallen, but not the standing, trees burnt out satisfactorily.

The results in general suggest that the use of ring-barking in clearing would be to ring in one dry season, protect from fire in the following dry season, then knock down the dead standing trees and burn in the second dry season from treatment. Further work on preparing the land for cltivation after the final burn is required before the method can be put forward as wholly satisfactory.

ACKNOWLEDGMENTS

I am indebted to Chief Research Division, Sudan Minitsry of Agriculture, for permission to publish this paper; to Professor A. H. Bunting, who suggested this work should be undertaken; and to P. K. S. Clinton, Esq., for notes on the plots in late 1956 after I had left the Sudan.

LEGUME NODULATION IN KENYA

I—EXPLORATORY FIELD EXPERIMENTS

By **E. D. Bumpus, Grassland Research Station, Department of Agriculture, Kenya**

(*Received for publication on 11th March, 1957*)

SUMMARY

A series of field experiments to test the effect of inoculants and phosphate fertilizer on legumes has demonstrated that for *A. glumaceus, T. labialis, M. sativa* (lucerne), *T. semipilosum* (Kenya white clover), *T. usambarense* (bitter lupin) and *T. subterraneum* (subterranean clover) there is a significant increase in the weight of nodulated plants compared with those which did not nodulate.

Under the same condtions subterranean clover has shown significant increases in yield and protein content.

The evidence obtained from these experiments, together with that obtained under laboratory conditions, using the same species of legumes and types of bacteria, strongly supports the view that the increase in yield of certain legumes as a result of inoculation and nodulation can be ascribed to nitrogen fixation.

It seems, therefore, that substantial nitrogen fixation can occur in legumes under field conditions in Kenya.

There is no doubt that well-known pasture legumes such as white clover (*Trifolium repens*) are able to "fix" atmospheric nitrogen in the temperate zones (Johnstone-Wallace [3], Sears [4] and Cowling and Green [1]), but corresponding evidence for pasture legumes in sub-tropical and tropical zones is almost lacking, and there does not appear to be any data of this kind up to the present time for pasture legumes in Kenya.

The reasons generally given for having a legume such as clover in a ley are that (*a*) it promotes increased production of herbage and of live-weight increase per acre as a result of the nitrogen fixed and made available by the legume; (*b*) it increases the supply of elements such as calcium and phosphorus for livestock owing to their greater richness in these constituents as compared to grasses; and (*c*) a well-managed grass-legume ley beneficially affects soil fertility.

In parts of Africa, within the tropical zones, the grass leys used in rotations usually consist of one grass only, e.g. Rhodes grass (*Chloris gayana*) or molasses grass (*Melinis minutiflora*) in Kenya, and star grass (*Cynodon* sp.) or Rhodes grass in Southern Rhodesia. Although considerable efforts have been made to find a suitable pasture legume for dry land leys in Kenya and Southern Rhodesia, for example, doubts have sometimes been raised about the wisdom of this policy in the high rainfall mixed farming areas of Kenya. It is contended in some quarters that the extra protein for livestock which would be provided, for example by Kenya white clover (*T. semipilosum*), would be provided during the growing season only and that there would be no contribution during the dry season, and also that the more serious shortage may be that of carbohydrates rather than protein.

Apart from doubts about the need for extra protein from a legume during the growing season, there has also been some uncertainty about the ability of pasture legumes to fix nitrogen under tropical and sub-tropical conditions. Quite a number of legumes occur widely in pastures in Kenya, some being found in natural grassland, and others invading sown grass leys, the particular species varying with the rainfall, the kind of soil and the altitude. Such legumes include, among others, *Alysicarpus glumaceus* (Alyce clover), *Glycine javanica, Teramnus repens, Indigofera* spp., *Trifolium semipilosum* (Kenya white clover), *T. johnstonii* (a purple perennial) and *T. rueppellianum* (an annual). It does not appear, however, that anyone has so far demonstrated an increase in the production of herbage or of animal live-weight, or an increase in soil fertility as a result of these legumes being associated with the grass.

If it is established that such legumes are in fact unable to fix nitrogen under Kenya conditions, and that the protein which they contribute is superfluous to the needs of livestock at the present time, then there would not be much of a case for including them in leys, except perhaps for the purpose of introducing variety in the herbage and for promoting a higher mineral status. However, Dougall (1953), who has worked on the composition of Kikuyu grass pastures, states with regard to the associated *T. semipilosum* that "there can be no doubt of its effect on the nutritive value of the sward", and that "in respect of crude proteins and minerals, especially CaO, the mixed herbage is of higher nutrient status than the grass alone, and it is less fibrous. The legume has clearly enhanced the feeding value of the pasture".

In view of the importance of knowing whether the pasture legumes mentioned above are able to produce nodules in which nitrogen fixation occurs, a number of simple field experiments were carried out in the seasons of 1954 and 1955 at the Grassland Research Station, Kitale, which is situated in one of the high rainfall mixed farming areas of Kenya.

The experiments to be described are of an exploratory character; it is hoped, however, that they will provide some guide as to the materials and techniques to be used in future experiments of a more critical nature. The ultimate object is to investigate more critically the nitrogen fixing abilities of the more promising pasture and forage legumes at present available in Kenya; their influence on the productivity of associated pasture grasses, and on soil fertility.

COMPARISON OF DIFFERENT INOCULANTS

The objects of this experiment were: (*a*) to ascertain whether various inoculants in commercial use produce enough difference in yield of plant material to make it worth while using some brands rather than others, (*b*) to observe whether there is any appreciable difference in nodulation percentage from different inoculants, and if so, if there is any definite association between high herbage yields and high nodulation percentages, and (*c*) to ascertain whether inoculated seed gives rise to greater yields of plant material compared with the uninoculated controls.

The four species selected for these experiments were *Medicago sativa* (lucerne), *Trifolium semipilosum* (Kenya white clover), *Alysicarpus glumaceus* (Alyce clover, an indigenous perennial) and *Teramnus labialis*, a small trailing perennial legume, also indigenous.

The inoculation groups to which these respectively belong are: (*a*) the lucerne group *Rhizobium meliloti*, (*b*) the clover group, *Rh. trifolii*, and the last two, to the cowpea group, *Rh. japonicum*. The inoculants used were obtained from Australia, the United States of America (two brands), England, South Africa, Sweden and Kenya.

In presenting the results, the various brands of commercial inoculants are not named, but the represented by the small letters (a) to (g).

The experimental design consisted of randomized blocks with eight plots per block, each plot having a different inoculant treatment, with three blocks. The plots were 6 ft. × 9 ft., with four rows of plants sown in each plot along the contour, with 18 in. between rows.

The blocks were arranged along the contour to reduce the possibility of wash from one plot to another, and were separated by pathways planted with *Digitaria swazilandensis*, a dense creeping grass, for the purpose of preventing wash and of reducing contamination of one block by another.

Comparisons between inoculant treatments were made by means of one large sample drawn from the middle of each plot. Each plot was divided into three equal strips 3 ft. × 6 ft. arranged lengthwise up and down the slope, the central plot being dug up for sample purposes and the strips on each side being left as discards against any contamination which might have taken place from neighbouring plots treated with the different makes of inoculant used for the same species.

The plants in the sample were dug out to a depth of 6in., and the adhering soil was slowly soaked off in a bowl of water so that any root nodules would be disturbed as little as possible and not shaken off. Root development and nodulation, if any, could now be examined clearly. Comparisons between different inoculant treatments were made by determining the total green weight of the plants in each sample, including their roots and nodules.

Results

The yield figures shown in Table I below are the mean weight in grammes of green material per plot sample for the three replicates of each treatment. The "percentage nodulation" figure is the percentage of the total number of plants in each treatment on which root nodules were found.

Discussion

Statistical analysis of these results does not indicate that any of the yield differences for the various treatments are significant, although it will be seen from Table I that differences between some of the treatments are substantial. The reasons for the lack of significance are considered to be due to attacks by chafer grubs on the roots, which caused irregular establishment and gaps in certain plots, and a previously unsuspected amount of soil heterogeneity within some of the blocks. There are, however, a number of points of interest which may be noted:—

(i) Relative production from different inoculants.

The differences between the highest and lowest mean yields for each species, due to different inoculants, are considerable: for example in *T. semipilosum* the lowest is 223 and the highest is 459; in *A. glumaceus* the percentage increase of the highest over the lowest is 163; in *T. labialis* it is 191, and in lucerne it is 52. It seems, therefore, that the various inoculants differ appreciably in their efficiency as measured by production of green weight of plant material per treatment.

TABLE I—EFFECT OF DIFFERENT INOCULANTS ON YIELD AND NODULATION

STRAIN OF INOCULANT	*T. semipilosum*		*A. glumaceus*		*T. labialis*		*M. sativa*	
	Yield*	per cent nodulation	Yield*	per cent nodulation	Yield*	per cent nodulation	Yield*	per cent nodulation
a	406	94	353	97	690	83	690	69
b	353	83	532	93	373	76	622	15
c	459	87	794	91	440	78	917	95
d	268	97	928	97	394	52	931	78
e	368	99	688	98	558	78	639	39
f	223	98	706	98	949	73	750	79
g	331	72	889	100	1,087	80	943	62
Control	327	72	1,070	96	492	80	497	6
Mean	342	87·75	745	96	623	75	749	55·4
S.E. of the mean ..	26·24	3·95	81	1·04	94	3·45	60	11·34

*Yield=grammes fresh material per plot.

(ii) Association of yield with percentage nodulation.

This does not seem to apply to *T. semipilosum*, and some of the low yields, e.g. in treatment "f" show a high percentage nodulation. In *A. glumaceus* the percentage nodulation is high throughout for both high and low yields. In *T. labialis* the results are somewhat inconsistent, while in lucerne there is some tendency for high yields and higher percentage nodulation to be associated, and lower yields with the lower percentage nodulation.

(iii) Comparison of treatment yields with the control.

In *T. semipilosum*, five treatments are better than the control and two are poorer, which would indicate that better results are obtainable by using a good inoculant than by relying on the presence of *Rhizobium* in the soil, as is the case in the control.

In *A. glumaceus* the control plot yield has surpassed all the inoculant treatments. It appears therefore that for this species none of the commercial strains of bacteria belonging to the "cowpea group" are as satisfactory as those already present in the soil. It may possibly be strain-specific and not even belong to the cowpea group at all.

In *T. labialis* three of the treatments are poorer than the control and four of them better, which would indicate that there may be an advantage in using a suitable inoculant for this species, and not relying on the strains present in the soil.

Lucerne.—In this species, the control shows the lowest nodulation percentage combined with the poorest yield. It seems fairly certain that there is no suitable *Rhizobium* in the soil for this species, especially as the genus *Medicago* is not represented in the local flora in this part of the Colony, and hence the advantage of inoculating the seed of lucerne. This finding accords with general experience in this area.

Comparison of Nodulated and Unnodulated Plants

A further objective in the foregoing experiment was to ascertain if any consistent differences would be found in mean weights of nodulated and of unnodulated plants in the various plots of each particular species examined. It was thought that as the nodulated and unnodulated plants were closely intermixed in each plot, the difference in mean weights of the two groups of plants could not be ascribed to soil heterogeneity. The only observable difference between the two kinds was that due to the presence or absence of nodules, though the reason for the plants behaving differently in this respect is not apparent.

The method used for making the comparison between nodulated and unnodulated plants was:—After soaking the soil off the roots as previously explained, to separate the nodulated and the unnodulated plants into two groups; each group was then weighed and the number of plants in each group counted. The mean weight of nodulated and unnodulated plants in each group was then calculated, and the comparison thereafter made by "Student's" '*t*' test. One difficulty encountered was that in some of the plots of certain species no unnodulated plants were found, and so these plots could not be included in the comparisons. The complete nodulation was no doubt due both to the use of an efficient inoculant and also, as will be explained later, probably to the use of phosphate.

The data obtained from the comparison on the different inoculants was also used for making the '*t*' tests when comparing the weights of nodulated and unnodulated plants.

The results from these were significant, and in favour of the nodulated plants in three out of four species, namely *Alysicarpus glumaceus, Teramnus labialis* and *Medicago sativa* (lucerne).

Results

The results of this experiment are given in Table II.

The figures represent the mean fresh weight in (g) of a nodulated and unnnodulated plant in each treatment.

As judged by "Student's" '*t*' test, these data favour the nodulated plants in *A. glumaceus, T. labialis* and *M. sativa.* In *T. semipilosum* the difference is not significant.

The percentage mean increases in weight of nodulated over unnodulated plants are shown at the bottom of Table II. Obviously at this stage these figures, namely 200 per cent for *A. glumaceus,* 27 per cent for *T. labialis* and 55 per cent for lucerne, should not be regarded as representative of the magnitude of increase to be expected normally in these species. They do indicate, however, that the nodulated plants in these experiments with typical root nodules show a larger mean weight than the unnodulated ones. Presumably the difference is due to nitrogen fixation taking place in the nodules of the plants possessing them.

Table II—Mean Fresh Weights of Nodulated and Unnodulated Plants of Four Species

Inoculant	*A. glumaceus*		*T. labialis*		*T. semipilosum*		*M. sativa*	
	Nodulated	Un-nodulated	Nodulated	Un-nodulated	Nodulated	Un-nodulated	Nodulated	Un-nodulated
a	14·81	4·0	5·25	3·23	8·52	6·21	6·97	2·29
b	20·08	11·5	2·92	1·71	19·58	13·55	8·23	8·97
c	20·34	14·0	6·18	3·83	18·42	17·12	11·29	8·4
d	25·07	14·6	2·72	2·46	8·15	17·00	12·90	9·30
e	22·92	1·0	4·79	2·02	9·90	1·00	12·14	9·47
f	19·26	2·5	5·76	4·93	6·08	10·32	11·60	7·10
g	21·35	None	6·41	4·98	10·87	10·72	14·92	4·59
Control	24·33	1·5	4·27	6·85	17·65	2·93	11·4	7·54
Mean	21·02	7·0	4·78	3·75	12·39	9·85	11·18	7·21
Increase of nodulated over unnodulated ..	200%		27%		26%		55%	
P*	0·001		0·02		n.s.		0·05	

*Calculated on original data.

The figures represent the mean fresh weight in g. of a nodulated and an unnodulated plant in each treatment.

COMPARISON OF FARMYARD MANURE AND FERTILIZERS ON KENYA WHITE CLOVER

The object of this exploratory experiment was to ascertain the effect of farmyard manure and fertilizers on the yield and nodulation of this species, and also to compare the mean weights of nodulated and unnodulated plants.

The design of this factorial experiment was an unreplicated 2^5 arrangement which included the presence or absence of five fertilizer treatments applied at the following rates per acre: sulphate of ammonia (n) 1 cwt., muriate of potash (k) 2 cwt., double superphosphates (p) 2 cwt., agricultural lime (l) 10 cwt., and farmyard manure (d) at five tons per acre. The plot size was 4 sq. yd. The clover was sown together with *Sporobolus filipes,* an indigenous pasture grass.

Results

Effects on Yield.—The differences in yield due to the various treatments were not significant. Table III shows that lime and potash tend to depress the yield, but the main increase in yield over the controls for two of the other three treatments were, farmyard manure 49 per cent and phosphate 19 per cent, while sulphate of ammonia made little or no difference.

TABLE III—MAIN EFFECTS OF FERTILIZER TREATMENTS

	Absence	Presence	Difference	Increase or decrease
				per cent
Nitrogen (n)	5,094·0	5,224·1	130·1	(+) 2·6
Phosphorus (p)	4,702	5,616·2	914·3	(+) 19·4
Potash (k) ..	5,788	4,530·2	1,257·7	(−) 21·7
F.Y.M. (d) ..	4,140	6,178·2	2,038·3	(+) 49·2
Lime (l) ..	5,639·7	4,678·4	961·3	(−) 17·0

Effect on nodulation.—Table IV shows the percentage of nodulated plants which were found in each of the fertilizer treatments:—

The percentage nodulation in 30 of the 32 treatments is between 95 and 100. In the control it is 79. It would appear from these figures that the effect of fertilizers on nodulation is beneficial, but one cannot draw any firm conclusions from one replicate only.

In view of the opinion, frequently expressed, that nitrogen retards the nodulation of legumes, it may be noted that more than half the plots receiving sulphate of ammonia at 1 cwt. per acre showed 100 per cent nodulation: further work, to be published shortly, has indicated that the sulphur in sulphate of ammonia has a beneficial effect.

It may be observed from Table IV that the top row of treatments which excludes lime and farmyard manure shows only one instance of 100 per cent nodulation, while the fourth row, which includes both these treatments, shows 100 per cent nodulation in all treatments except one. The other two rows, with the lime combinations, and with the farmyard manure combinations, are intermediate in the number of treatments showing 100 per cent nodulation.

Comparison of nodulated and unnodulated plants of T. semipilosum.—The fertilizer treatments in which both these occurred are given in Table V below, together with the mean fresh weights of nodulated and unnodulated plants, and also the weight differences between them.

TABLE IV—PERCENTAGE OF PLANTS NODULATED IN EACH TREATMENT

None	n	p	np	k	nk	pk	npk
79	98	98	100	96	95	97	82
l	nl	pl	npl	kl	nkl	pkl	npkl
100	97	99	100	100	100	100	100
d	nd	pd	npd	kd	nkd	pkd	npkd
98	96	100	100	100	100	97	100
ld	nld	pld	npld	kld	nkld	pkld	npkld
95	100	100	100	100	100	100	100

TABLE V—MEAN WEIGHTS OF NODULATED AND UNNODULATED PLANTS UNDER VARIOUS FERTILIZER TREATMENTS

Treatment	Nodulated	Unnodulated	Difference
Control	0·4	0·3	0·1
n	1·9	0·3	1·6
p	3·5	3·0	0·5
k	1·5	0·6	0·9
nk	3·3	0·5	2·8
pk	6·3	1·9	4·4
npk	0·8	1·1	(—) 0·3
nl	5·2	2·3	2·9
pl	3·6	0·8	2·8
d	3·0	1·6	1·4
nd	2·6	1·1	1·5
pkd	6·1	0·6	5·5
ld	4·4	3·4	1·0

S.E. of the mean difference=0·47. Mean difference=1·9

The *'t'* test shows a significant difference in favour of the nodulated plants at P = 0.01 per cent. It seems likely, therefore, that the greater weight of the nodulated plants may be due to the fixation of nitrogen which has taken place in the nodules. In comparison with the previous experiment on *T. semipilosum*, in which no positive result was obtained, the significant difference obtained here is believed to be due to the various fertilizers which were applied.

EFFECT OF INOCULANTS AND FERTILIZERS ON GROWTH AND PERCENTAGE NODULATION

The object of this experiment was to determine the percentage of nodulated plants which occurred, and the increase in weight due to nodulation, in a number of legumes grown with and without various fertilizers and trace elements, in the presence and absence of an appropriate inoculant.

The species used in this experiment were: *Alysicarpus glumaceus*, *Crotalaria incana*, *Dolichos lablab* (annual), *Lespedeza stipulacea*, *Lupinus albus* (bitter lupin), *L. luteus* and *L. angustifolius* (yellow and blue sweet lupins), *Lotononis bainesii*, *Medicago denticulata*, *Medicago sativa* (lucerne), *Phaseolus coccineus* var. *albus*, *Teramnus labialis*, *Teramnus repens*, *Trifolium alexandrinum* (Berseem clover), *T. cheranganiense*, *T. johnstonii*, *T. repens* (Ladino var.), *T. repens* (Louisiana var.), *T. semipilosum* (Kenya white clover), *T. steudneri*, *T. subteraneum* (Yarloop and Mount Barker var.), *T. tembense*, *T. usambarense* and *Vigna sinensis* (cowpea).

The treatments were as follows:—

Group I, uninoculated seed

(*a*) Lime, potash and phosphate applied together, along with compounds of six trace elements, magnesium, manganese molybdenum, boron, copper and zinc.

(*b*) Phosphate alone.

(*c*) Control: no fertilizer or lime, no trace elements and no inoculantts.

Group II, all seed inoculated

(*d*) Control.

(*e*) Phosphate alone.

(*f*) Phosphate plus the six trace elements used in (*a*) above.

(*g*) Lime, potash, phosphate and trace elements as in (*a*) above.

The rates of application per acre to the plots were: lime 10 cwt., double superphosphate 1 cwt., muriate of potash 1 cwt., copper sulphate 20 lb., zinc sulphate 10 lb., molybdic acid 2 lb., magnesium sulphate 60 lb. and manganese sulphate 10 lb. per acre. Individual plots were 6 ft. × 9 ft.

The reason for the treatment (*f*) not being present in the uninoculated series was the absence of sufficient space between the two contour banks.

The legumes were sown in strips across the above treatments, the latter being arranged in strips along the contour. The uninoculated treatment strips were placed above the inoculated treatments on the slope, in order to avoid possible contamination by means of rain washing soil down the slope.

Sampling strips 6 ft. × 3 ft. were dug lengthways up and down the slopes in the centre of each plot, and the plants were dug up by a hand-fork, placed in a bowl of water to soak off the soil, and dealt with as before.

Results

The only species which gave significant yield results were bitter lupins, Mount Barker subterranean clover and *Trifolium usambarense*.

The percentage of nodulated plants obtained from each of these species is given in Table VI.

As the fertilizer treatments are not replicated the results given in Table VI should be viewed with reserve. It may be noted, however, that *T. usambarense*, an indigenous annual, shows 100 per cent nodulation with the no-fertilizer

TABLE VI—PERCENTAGE OF NODULATED PLANTS UNDER VARIOUS TREATMENTS

LEGUME	UNINOCULATED TREATMENTS			INOCULATED TREATMENTS			
	Ca, P, K tr.	P	Nil	Nil	P	P and tr	Ca, P, K, tr.
T. usambarense	100	96	100	100	100	94	98
Bitter lupin	55	83	82	96	78	50	78
Sub. Clover	96	83	77	99	100	100	100

treatments in both inoculated and uninoculated plots. Its percentage nodulation appears to be little affected by the various treatments.

In the bitter lupin series, the inoculated plots for the no-fertilizer treatment, and for the Ca, P. K. trace elements treatment, show a higher percentage nodulation than the corresponding uninoculated plots. The subterranean clover shows 100 per cent nodulation only in the inoculated plots which receive phosphate. This species is not indigenous, and a strong response to the inoculant can be consistently observed in the field plots. After two months or so, however, the bacteria appear to spread widely, and eventually they induce nodulation and bring about more vigorous growth in the uninoculated plots.

In Table VII the inoculated plants of *T. usambarense* show a substantial increase in weight compared with the uninoculated ones. Although the percentage of nodulated plants is not much affected by applying an inoculant, it seems that inoculation has conferred much benefit, as judged by the percentage increase in weights. Presumably the nodulated plants in the uninoculated plots were infected from the soil, or by contamination, and later on, from the inoculated plots; whatever the source of the bacteria, they have not done so well as the plots deliberately inoculated at the start of the experiment.

TABLE VII—MEAN PERCENTAGE INCREASE IN WEIGHT OF NODULATED OVER UNNODULATED PLANTS

LEGUME	On three uninoculated plots	On four inoculated plots	For all treatments over seven plots
T. usambarense	37	469	159
Bitter lupin	27	159	88
Sub. Clover	20	40	30

In the case of bitter lupins, inoculation has also conferred benefit in the form of a substantial increase in weight of nodulated compared with unnodulated plants, though to a lesser extent than in *T. usambarense*. The same remarks apply in lesser degree to Mount Barker subterranean clover.

The mean weight of the nodulated and unnodulated plants are given in Table VIII for each species, for plots in which both kinds were found. On some plots no unnodulated plants were found, and the results for these plots could not, therefore, be used for the '*t*' test.

TABLE VIII—COMPARISON OF MEAN WEIGHTS OF NODULATED AND UNNODULATED PLANTS

SPECIES	Treatment	Mean weight nodulated plants	Mean weight unnodulated plants	Difference	Significant at
T. usambarense	p. uninoc.	5·7 gm.	3·6 gm.	2·1 gm.	
	p. tr. inoc.	4·2	0·8	3·4	
	pkl. tr. inoc.	3·9	0·5	3·4	P=0·05
Bitter Lupin	pkl. uninoc.	0·165 lb.	0·136 lb.	0·029 lb.	
	p. uninoc.	0·343	0·300	0·043	
	Control, uninoc.	0·182	0·111	0·071	
	Control, inoc.	0·271	0·075	0·196	
	p. inoc.	0·384	0·240	0·144	
	p. tr. inoc.	0·188	0·052	0·136	
	pkl. tr. inoc.	0·412	0·040	0·372	P=0·02
Sub. Clover	pkl. tr. uninoc.	0·038 lb.	0·034 lb.	0·004 lb.	
	p. uninoc.	0·049	0·040	0·009	
	Control, uninoc.	0·021	0·016	0·005	
	Control, inoc.	0·041	0·030	0·011	P=0·02

Treatments: p=phosphate, k=potash, l=lime, tr.=trace elements, inoc.=inoculated seed, uninoc.=uninoculated seed.

EFFECT OF PHOSPHATE AND INOCULANT ON SUBTERRANEAN CLOVER

The object of this experiment was to examine more critically the effects of phosphate and a good inoculant on the growth, nodulation and nitrogen fixation of subterranean clover, in view of the observed marked effects of these two treatments in previous experiments. The "Yarloop" variety of subterranean clover was used in this experiment.

Treatments.—Double superphosphate at 2 cwt. per acre and the "Nodulaid" strain of inoculant from Australia. The treatment combinations were:—

(*a*) With phosphate and with inoculant.

(*b*) With phosphate and with no inoculant.

(*c*) Without phosphate and with inoculant.

(*d*) Without phosphate and without inoculant.

The treatments were arranged in three randomized blocks, the plot size being 6 yd. × 4 yd. The clover was sown in rows 1 ft. apart. The sowing date was 6th July, 1955, and the herbage was harvested between 21st and 23rd September, 1955, a growth period of 11 weeks.

Results

The mean results of the various treatments in yields per acre are given in Table IX:—

Chemical analyses were carried out on samples from the four treatments, and these results are shown below in Table X. The first four columns show the chemical analysis under the particular treatments indicated, while the second four columns, headed "Mean Effect", give the means of the four pairs of treatments.

TABLE IX—YIELD OF DRY MATTER AND OF NUTRIENTS (lb. per acre)

Treatments	Dry Matter	Carbo-hydrate	Crude Protein	Ca.	P
Minus inoculant minus phosphate	468	277	66	6·22	0·8
Plus inoculant minus phosphate	884	484	171	10·96	1·6
Minus inoculant plus phosphate	1,612	948	225	17·4	4·4
Plus inoculant plus phosphate	3,796	2,030	669	44·0	9·5
Means ..	1,690·0	934·8	282·8	19·7	4·1
S.E. of the mean	400				

Standard error=23·5% of mean plot yields.

Differences between treatments significant at P=0·001%

The silica-free ash is increased both by phosphate fertilizer and by inoculation, and it is highest in the presence of both. The crude protein and true protein is greater in each case in the presence of inoculant, and in the absence of phosphate, though the digestibility of the crude protein appears to be slightly increased in the presence of inoculation.

In respect of the minerals, the mean figure for calcium indicates that this element is depressed slightly in the presence of phosphate and not affected by inoculation. The phosphorus, on the other hand, increases in response to the phosphatic fertilizer, but seems unaffected by inoculation.

DISCUSSION

As some of the foregoing experiments did not produce significant results, the findings from them can only be regarded as preliminary indications.

TABLE X—CHEMICAL ANALYSIS OF SUBTERRANEAN CLOVER UNDER FOUR DIFFERENT TREATMENTS

COMPONENT	(PER CENT OF DRY MATTER)							
	TREATMENT				MEAN EFFECT OF			
	+ Inoc. + P	− Inoc. + P	+ Inoc. − P	− Inoc. − P	+ P	− P	+ Inoc.	− Inoc.
Silica-free ash ..	10·64	9·10	10·09	9·28	9·87	9·69	10·37	9·19
Crude protein ..	17·62	13·98	19·44	14·24	15·80	16·84	18·53	14·11
True protein ..	14·54	12·11	16·73	12·53	13·33	14·61	15·64	12·32
Digestibility of crude protein* (per cent)	83·87	81·81	83·95	80·52	82·84	82·24	83·91	81·17
Ether extract ..	2·64	2·43	2·80	2·62	2·54	2·71	2·72	2·53
Crude fibre ..	13·54	12·18	11·98	12·53	12·86	12·26	12·76	12·36
P	0·25	0·27	0·19	0·18	0·26	0·19	0·22	0·23
Ca.	1·16	1·08	1·24	1·33	1·12	1·29	1·20	1·21
Carbohydrate ..	53·49	58·80	54·78	59·17	56·15	56·98	54·14	58·99

*By pepsin digestion

Where significant results have been obtained, however, as with the increase in weight of nodulated compared with unnodulated plants, and the increased yields of dry matter and of protein in the inoculated treatments, it would appear that nitrogen fixation can occur in these particular legumes under field conditions in Kenya. This view is supported by work done by Nattrass and his colleagues at the Scott Agricultural Laboratories in Nairobi, who isolate the nodule bacteria from these same legumes growing in field plots, and grow these same species with the bacteria so obtained, from seed, under laboratory conditions, in cultures containing no nitrogen. The plants thus grown develop normally, have a healthy green colour, and produce characteristic root nodules. The uninoculated controls, on the other hand, do not develop at all.

This present work shows that the nodules of the plants growing in the field contain bacteria which are able to fix nitrogen under controlled laboratory conditions. From the foregoing experimental evidence, therefore, it seems extremely likely that the increased weight of nodulated plants, and the increased protein content and yields due to inoculation, are due to a process of nitrogen fixation.

Under field conditions at Kitale, it appears that a supply of readily available phosphate, such as 1 cwt. per acre of double superphosphate, and the right strain of inoculant, are two of the most important factors for ensuring nodulation and efficient nitrogen fixation, and this has been further borne out in more recent experiments. The importance of not rejecting a legume under trial until it has succeeded in nodulating properly with the right strain of inoculant, can hardly be overemphasized. In fact a number of legumes which were rejected previously are now being grown successfully and are yielding well, after being supplied with the right inoculant and a moderate dressing of fertilizer phosphate. The most striking example of this is subterranean clover.

ACKNOWLEDGMENTS

The author is much indebted to Dr. H. W. Dougall, for advice and criticism during the preparation of the manuscript, and also to Miss B. R. Trelawny and Mr. John N. Murage for checking the calculations. He also wishes to acknowledge the assistance received from Dr. R. M. Nattrass, Senior Plant Pathologist, and Mr. R. A. Robinson, Plant Pathologist of the Scott Agricultural Laboratories, Nairobi.

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DIEBACK OF WATTLE—A BORON DEFICIENCY

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(*Received for publication on* 18*th April,* 1957)

In 1954 an investigation was started by the Government Chemist's Department, Dar es Salaam, in collaboration with officers of the Colonial Development Corporation on a dieback disease of black wattle (*Acacia mollisima* Wild). The disease was causing some interference with the maintenance and thinning programmes of the corporation's wattle estates at Njombe in the Southern Highlands Province of Tanganyika. This investigation has now indicated that the disease is caused by a deficiency of boron and since it is suspected that this disease occurs in other parts of East Africa, these notes on the occurrence, cause and correction of the dieback may be of interest to wattle planters. Since the soil types found on the Njombe Wattle Estates are not uncommon in the Southern Highlands of Tanganyika and may occur in other regions as well, our results are also of significance to those engaged in soil fertility investigations in connexion with crops or trees other than wattle. It is believed that this is the first recorded instance of boron deficiency in wattle.

At Njombe the wattle trees are first affected mainly during their second dry season after seeding, that is when they are 18 to 22 months old. A few trees in their first or third dry season are affected but the number is small. The disease first becomes noticeable in late July or August (the rains at Njombe usually finish in May or early June) and fresh incidence only stops with the onset of the rains during the following November or December.

The disease occurs sporadically in the vulnerable age class and spreads erratically, but there is a marked tendency for it to occur in patches. For example, the overall incidence over many thousands of acres at Njombe is is probably only about 0.1 per cent, but in the badly affected patches 90 per cent or more of the trees may be attacked in their second year, and only about 40 per cent of the attacked trees can be expected to recover. Furthermore the recurrence of the disease during the third dry season in trees which recover from their first attack averages 40–50 per cent.

These incidence figures refer only to the estates on which this investigation was carried out. In another area of the Southern Highlands a small wattle planting scheme is 80 per cent understocked over half its area and 50 per cent understocked over the other half as a result of dieback disease.

The first outwardly visible sign of the disease is the drying, withering and death of the apical shoot, rapidly followed by death, in a similar manner, of the apices of the branches. Defoliation and death then spread steadily downwards and inwards from the apices. If the rains start before a tree is quite dead it will make a partial recovery and throw out fresh leaders, but these often suffer further attacks in subsequent dry seasons until the tree succumbs.

Microscopic examination of the tissues of affected trees shows that the cambial cells in the region of the apical meristems, and of the root collar, collapse into a structureless brown mass. This necrosis of the cambial tissue spreads along and around the stem until the tree is dead or the first rains check the disease. We believe that collapse of the cambium is the first stage of the disease and precedes visible dieback.

Dieback symptoms have been produced experimentally in three-month-old wattle in sand culture by withholding boron [4], [5]. The withering of the apical shoot and the browning of the cambial layer which have occurred are typical of the field condition. A blue fluorescence under ultraviolet light, such as is commonly found in the necrotic areas of boron-deficient celery, tomatoes, lettuce, radish and sunflower, has also been found in the stem of the withering apical shoot of the boron-withheld plants but not in similar parts of the healthy boron-supplied plants. It is now intended to supply boron to the boron-withheld plant in an attempt to induce healthy secondary growth.

In this connexion it is interesting to note that a recent review [1] of the functions of boron in plants comes to the conclusion that boron is very important in cell division, being apparently a necessary component of the cell wall.

No pathological organisms have been detected in the diseased trees and there appears to be no relationship between incidence and microclimate or cultivation. It occurs both in trees competing against dense weed growth and in those growing on "clean" areas. It is seen as often in wind-exposed sites as on sheltered slopes, and the possibility of the damage being due to frost has been eliminated. This disease also occurs on both of the two main soil types on the estates.

These facts point to a nutritional disturbance. Our procedure in such cases is to study the symptoms of the disease, the history and present characteristics of the soil, and to compare leaf composition of diseased and healthy trees. Leaf analysis is very often the main line of attack and all the 12 nutrients known to be essential to healthy plant growth are estimated. From these converging approaches to the problem it is usually possible to narrow the field of likely deficiencies to three or four elements, which are then applied to the crop in simple field trials. In these preliminary field trials the trace elements are applied in solution as foliar sprays while the major nutrients go on to the soil. Plants are able to absorb nutrients quickly and efficiently through their leaves; by this means more rapid responses are obtained than can be expected from soil applications and complex soil interactions are avoided. In other words, foliar spraying used as a diagnostic technique.

The sporadic or scattered outbreak of the disease indicates a deficiency of a trace or micro-nutrient element in which the deficiency is relatively slight and the symptoms are consistent with those usually found in boron, calcium and possibly copper deficiency.

The soil at Njombe is a deep, intensely leached red earth of the sesquioxide-kaolinite type which is overlain in places by a soil derived from ash from the Rungwe volcanic focus. Though younger than the red earth the volcanic ash soil has, from a chemical point of view, reached a mature stage in its development and has a composition approaching that of the red earth soil. Deficiencies of micro-nutrient elements in these soils can be expected on pedological grounds. It seems that the intensity of soil weathering rather than the soil parent material is generally responsible for nutrient poverty. The nutrients most likely to be deficient are phosphorus, calcium, boron, sulphur, molybdenum and zinc [2]. Soils similar to the Njombe soils are found at Mbozi where investigations have shown coffee yields to be restricted by zinc and boron deficiencies.

The comparative analysis of leaves from healthy and diseased trees, confined at first to the more mature leaves, showed that there was less phosphorus, sulphur and calcium in the latter. There was no significant difference between the levels of the other essential elements in the two samples. However, comparison was later made of these analytical results with those for other trees and crops, and this suggested that the levels of boron and molybdenum were low in both the healthy and the diseased wattle. In cases where a slight deficiency may be affecting a large area it is quite possible that leaf analysis will not show any significant differences, as far as the limiting deficient element is concerned, between the so-called healthy and the diseased samples since, if all the trees in the area are on the border line of deficiency, levels of the critical element will be low in both samples. For this reason, where possible, leaf analysis should compare leaves from diseased trees, or trees that are in a vulnerable site, with samples from an entirely separate site, where the trees are known to be in first-class condition. A site was later selected at Njombe where dieback had never occurred and by analysing only younger leaves—in which probably boron is in greatest demand—more evidence on the relation of boron to dieback of wattle was obtained, as is shown in Table I:—

TABLE I

Composite leaf sample (70–100 trees)	*Boron in dry leaf material (Parts per million)*
Apparently healthy trees from dieback site	11.2
Trees with dieback from dieback site	7.2
Healthy trees from non-dieback site	20.4

In 1954 a small interim trial was laid down, mainly on the basis of our preliminary work on the more mature leaf material. It consisted of spray application of calcium, sulphur, phosphorus and molybdenum and gave negative results. In 1955 the conclusions drawn from all the evidence outlined above indicated that boron and zinc should also be included in the trials and a simple experiment was designed in which spray applications of boron, zinc and molybdenum, separately and in combination, were superimposed on soil applications of calcium and phosphorus (as double superphosphate) and sulphur (as ammonium sulphate). The treatments were applied in May to a block of 18-month-old trees, and the spray treatment was repeated in August.

The results of the experiment are summarized in Table II:—

TABLE II

SPRAY APPLICATIONS REGARDLESS OF SOIL TREATMENT

Treatment	*Percentage of treated trees attacked by dieback during the season per cent*
No spray	32.5
Molybdenum	47.0
Zinc	45.0
Zinc and molybdenum	34.0
Boron	Nil
Boron and zinc ..	Nil
Boron & molybdenum	Nil
Boron, zinc and molybdenum	Nil

SOIL APPLICATIONS REGARDLESS OF SPRAY TREATMENT

(These treatments were applied in blocks and therefore include boron-treated trees, consequently the overall percentages for the blocks are lower than for the individual rows of sprayed trees.)

No soil application (two blocks)	12.5 and 7.5
Double superphosphate	10.0
Ammonium sulphate	27.5
Double super and ammonium sulphate	32.5

Controls.—The incidence of the disease in the control blocks, which received neither soil or spray treatment, varied between 15 per cent and 65 per cent.

The results from this trial indicate that a deficiency of boron, and probably boron only, is responsible for this particular form of dieback in wattle, and that relatively small applications of boron will prevent the onset of the disease. The boron in the above experiment was applied as a 0.25 per cent solution of borax in water at a rate equivalent to approximately 7 lb. of borax per acre, or 14 lb. per acre over the whole season. Furthermore, evidence from other sources suggests that the second spraying in the same season is not necessary if the first one is given at the right time. Experiments to prove this are to be carried out.

In areas where water is in limited supply or is difficult to transport, soil applications of boron are likely to be cheaper than spray treatment of the foliage despite the fact that soil doses usually have to be higher than those for sprays to produce the same effect. An experiment to test the effect of soil applications has been carried out and shown that 20 lb. of borax per acre will reduce the incidence of dieback. It will now be necessary to experiment with larger doses to determine the amount required to effect complete control.

It is not yet known for how many seasons it will be necessary to repeat applications of boron in affected areas. That dieback can attack trees that have been sprayed with borax solutions during a previous season has been established, and there is evidence that there is a greater tendency in this direction when trees are receiving superphosphate as fertilizer. On the other hand there is no doubt that, at Njombe, the trees become progressively less prone to attack as they grow older. Probably the number of years over which the treatment must be continued to eliminate the disease entirely will simply depend on the severity of the boron deficiency at the particular site in question.

Although the immediate objective of this investigation has been reached, several interesting points were brought to light during the work. It is clear that the Njombe soil is not well supplied with the other nutrients besides boron and it is quite possible that responses to these could be obtained once the boron deficiency has been corrected. It may be that wattle is not very demanding, but on the other hand excellent responses have been obtained to phosphorus and the fact that the leaf analyses revealed shortages of calcium, sulphur and possibly molybdenum as well as phosphorus, in the poorer trees should not be ignored. Furthermore, the application of ammonium sulphate to the soil, or zinc and molybdenum to the foliage, in the absence of boron, appeared to produce an increased degree of attack by dieback. This may mean that sulphur, zinc and molybdenum are at sub-optimum levels at Njombe and that the initial response to these elements merely accentuates the limiting factor which is the boron deficiency. Since, however, the wattle trees grow adequately once they have got over the boron-deficient stage it is possible that responses to other elements may be too small to be of economic value or in the case of phosphorus fertilizers—a macro-nutrient fertilizer usually required in larger amounts than a micro-nutrient fertilizer—the transport charges may be prohibitive.

Another significant point that has emerged is that dieback diseases with symptoms very similar to those of wattle dieback occur in other species of trees which are widely separated taxonomically from wattle [3]. For example dieback diseases have been reported in *Pinus patula* and *P. radiata* at Mbeya and in *Eucalyptus* sp. and *Grevillea robusta* at Mufindi. The pine dieback disease is under investigation and it has already been shown on a small scale that it can be corrected by the application of boron and zinc, though it has not yet been established whether zinc is essential.

Perhaps the most interesting feature of the wattle dieback disease is that at Njombe it strikes mainly in the second dry season. Since the older trees are healthy it appears that wattle is normally just able to satisfy its minimal needs given sufficient moisture and an adequate foraging root system. When a soil dries out nutrient availability falls off sharply and this may lead to temporary deficiencies from which a tree can recover only when the soil becomes moist again. If wattle is somewhere near its lower limit of satisfactory nutrition with respect to boron, moisture levels will be of critical importance each dry season. It would be interesting to know if irrigation at the crucial time of the year would prevent attacks of dieback at Njombe, though, of course, it is not suggested that this would be a practical solution to the problem on a large scale in view of its cost as compared with the application of boron. Freedom from the disease after a certain stage may well be due to increased root range, either laterally or in depth, which enables the tree to obtain sufficient boron despite the decrease in its availability each dry season, combined with the fact that the older the tree the less may be its demand for boron. Trees in their second year, on the other hand, will probably have a high demand for boron, they will have exhausted the boron reserves in the seed, which may perhaps have seen them through their first dry season, and their root system may simply be inadequate to obtain what they need. It would be interesting to know if there are areas in East Africa where the amount of available boron in the soil is less than at Njombe, and whether, as a result, wattle is liable to atttack by dieback at any stage in its life during a prolonged dry season.

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REVIEW

CHEMICALS, HUMUS AND THE SOIL, by D. P. Hopkins. Published by Faber and Faber, London. Revised Edition. 1957. Price 25s.

Nearly ten years have elapsed since the last edition of this book, years in which the matter of "Humus versus Chemicals" has remained almost as controversial as ever. The author has bridged the gap of a decade by adding several new chapters and rewriting others. In its present form the book is divided into three parts: "The Case for Fertilizers", "The Case Against Fertilizers" and "The Case for More Fertilizers". Whereas the scienitfically minded can do no better than to read straight through the volume, the layman would be better advised to commence with Part II, which is less technical and certainly more interesting. Both sides of the question are presented with scrupulous fairness, but the author has succeeded, by the very virtue of that fairness, in damning the case of the "anti-chemicals" school. While the book is largely a discussion of the pros and cons of chemical fertilizers, it contains many points of practical interest to the farmer, and on this account it deserves a place on his bookshelf.

P. R. H.

FUNGUS COMBS IN TERMITE MOUNDS

By P. R. Hesse, East African Agriculture and Forestry Research Organization, Muguga, Kenya

(*Received for publication on* 13*th May,* 1957)

A typical feature of the large termite mounds found in central Africa is the presence of so-called "fungus comb". On digging into a mound these irregular, sponge-like masses are revealed; some resting in their own individual chambers (Fig. 1) and others carefully built into the earthen framework of the nest (Fig. 2). The comb is prepared from vegetable matter collected and processed by the worker caste of termite, and almost any kind of raw material is utilized providing that it contains a high percentage of cellulose. Thus grass, leaves, semi-decomposed pieces of wood and paper have been known to form the basis of fungus comb. Once brought into the mound the coarse vegetable debris is stored in chambers until required (Fig. 3). Subsequently it is chewed by the worker termites and made into a paste with their saliva, after which it is moulded into the structure of the mound.

It is contended by some entomologists that part, at least, of the fungus comb is formed from the excreta of the termites, and some investigators go so far as to suggest that fungus combs are merely the defaecation sites of the insects. Whilst the latter suggestion is highly improbable, it is not yet known with certainty whether the comb is formed from comminuted wood chewed by the termites or from vegetable matter passed through the gut.

As for the appellation "fungus comb", this is due to the fact that a fungus is invariably found growing on the material and is normally seen as small white balls dotted over the surface of the comb (Fig. 4). Sometimes the term "fungus gardens" is heard and this is because of the widely held belief that the termites prepare the comb for the specific purpose of growing the fungus as food. The presence of a fungal growth on the comb is not surprising. It has been demonstrated (Kofoid, 1934) that during their foraging expeditions the termites transfer fungus spores from rotting vegetation to the interior of their mounds. Thereafter the unvarying warm and humid conditions found in a termite mound, which are so suitable for the well-being of the colony, are also ideally suited to the growth and development of the fungi.

As previously mentioned, a prevalent theory as to why termites prepare fungus combs is that the insects utilize the damp warm woody material on which to grow fungus as food. It is an undisputed fact that termites do eat fungus, but whether they do this as a predetermined procedure or whether it is that the fungus just happens to be a handy food is not so certain. If the growing threads of fungus were not eaten they would rapidly develop as shown in Fig. 5, which depicts the result of two days' incubation of a small piece of comb.

An alternative theory has been advanced by Harris (1951), who suggests that the combs are principally humidifiers or air-conditioners in the mounds. The cellular structure and large surface area of the comb can efficiently absorb excess moisture from the atmosphere, such as that caused by condensation on the entrance of cooler air, and return it to the atmosphere when the humidity falls again. As the humidity inside a mound is almost at saturation point, and as *Macrotermes* exist in such extremes of external climate as the dry deserts of Northern Kenya and the moist regions of the coast, some such humidity control appears to be essential.

Harris also suggested that, besides controlling the humidity, fungus combs act as nurseries for the young termites. He describes how the eggs from the queen are incubated in the fungus nurseries in which the delicate larvae remain until fully grown; by living in the combs they are ensured of safety from sudden temperature or humidity changes. However, I have never found termite eggs or larvae on fungus combs, but rather in small earth chambers around and adjoining that of the queen.

It has often been stated that such large concentrations of vegetable matter inside mounds must enrich the soil in minerals, and this has been put forward as an explanation of the observed fact that some termite mounds form localized patches of highly fertile soil. It has been shown, however (Hesse, 1955), that this is not the case, and that any increase in fertility of a termite mound over the adjacent land is entirely due to its physical structure.

A typical analysis of fungus comb is given in Table I, from which it can be seen that the

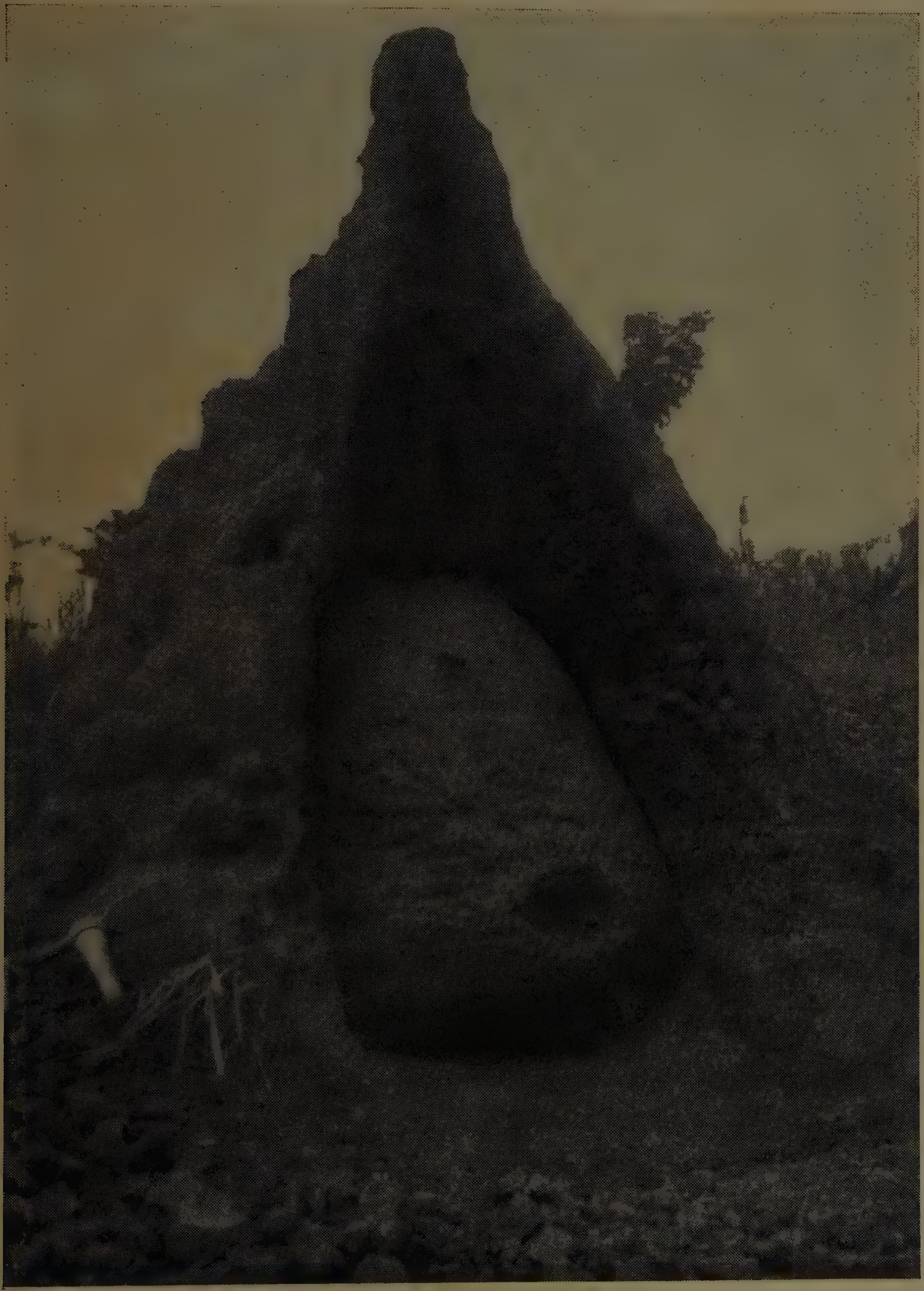

Fig. 1.—The interior of a M. natalensis mound showing fungus combs in small pockets of the outer shell

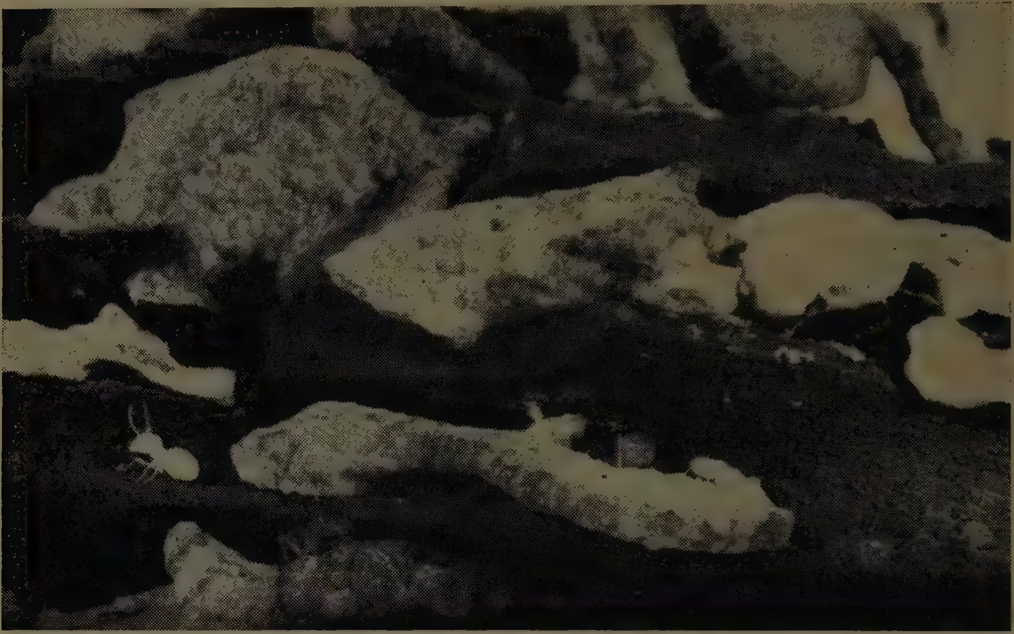

Fig. 2.—Fungus comb built into the earthen framework of a M. bellicosus mound.

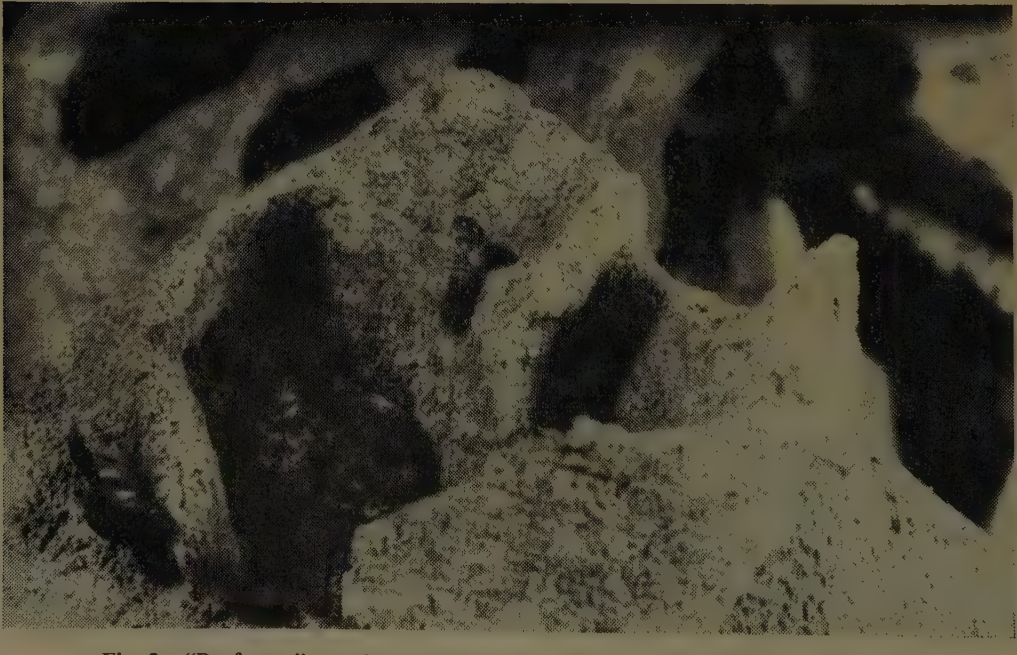

Fig. 3.—"Pre-fungus", woody-material in an earthen cellar of a M. bellicosus mound

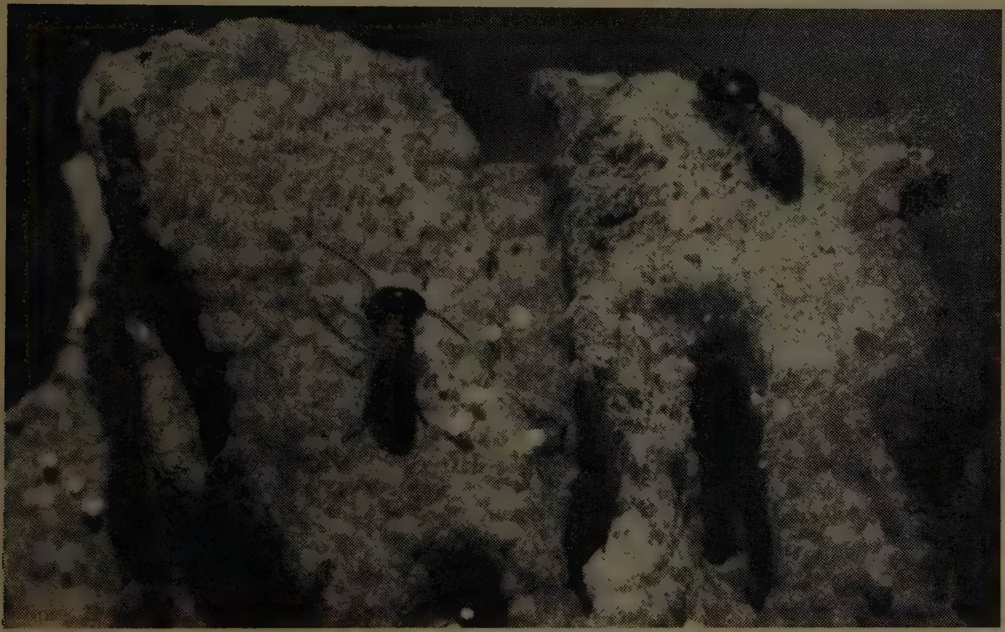

Fig. 4.—White balls of fungus growing on a piece of comb from a M. bellicosus mound

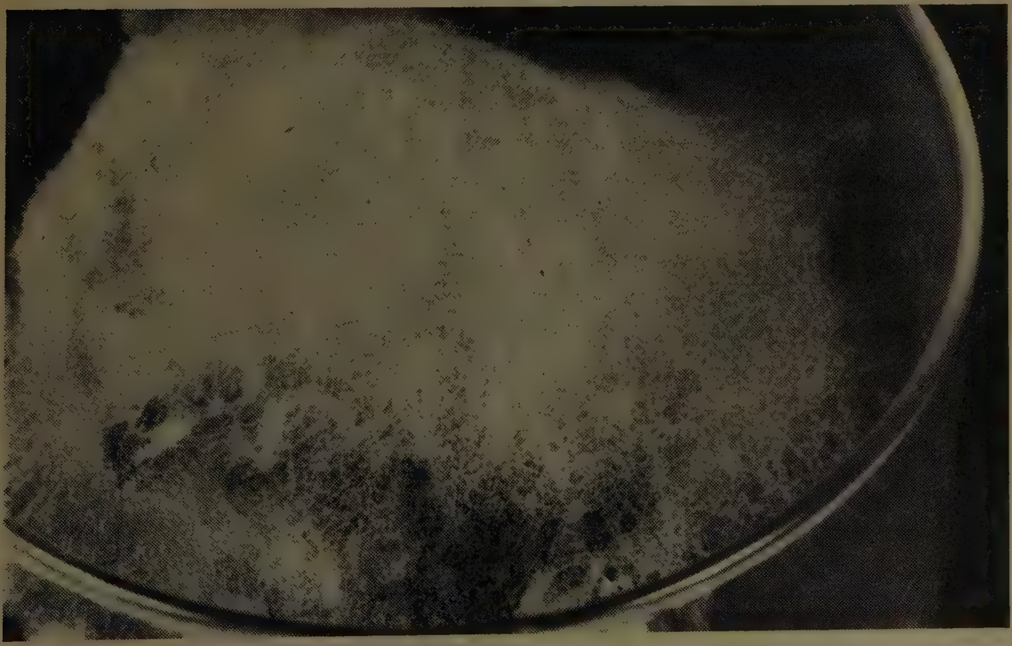

Fig. 5.—Growth of fungus obtained on incubation of a small piece of comb

comb consists mainly of water, cellulose, silica and an organic water-soluble material. A high cellulose content was to be expected, considering the source of the material, and the silica is probably due to contamination with soil. Calcium is the most abundant and important of the mineral constituents, and is present to approximately 1 per cent of the dry fungus comb. A typical uninhabited fertile termite mound was shown to contain 12 kg. of calcium in excess of that in a similar bulk of nearby soil. If this excess calcium was derived from fungus comb 1,200 kg. of the material would be required. Owing to its cellular structure fungus comb occupies a relatively large volume for its weight and 1,200 kg. would occupy 17 cubic metres, or over 50 times the volume of the mound. Thus the large concentrations of calcium which are found in some termite mounds cannot be accounted for by the fungus combs, but an explanation of their occurrence has been put forward in detail by the author (Hesse, 1955) and can be summarized as follows. When a termite mound has been built near land of poor drainage and when termite activity within that mound has ceased, then it acts as a small area with greater evaporating powers than the surrounding soil. Several factors cause enhanced evaporation from such a mound, the most important being its elevated position, its tunnels and its vegetation. In poorly drained soils the vegetation is often confined as clumps on old termite mounds which leads to greater transpiration. Calcium, in the form of soluble bicarbonate in the groundwaters, is thus drawn towards the mounds, and on evaporation of the water insoluble calcium carbonate is precipitated. Naturally, an accumulation of calcium will take a long time, and indeed it is only in very old heaps that deposits of calcium salts are found.

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Table I—Chemical Analysis of Fungus Comb

			Dry Material											
Sample	pH	% Moist when fresh	% Ash	% SiO_2	% R_2O_3	% Ca	% Mg	% Mn	% K	% Na	% P	% N	% Cellulose	% Water Soluble Matter
From a *M. goliath* mound	4·3	56·3	23·9	12·5	2·6	1·1	0·4	0·3	0·4	nil	0·3	1·5	27·1	22·9
From a *M. bellicosus* mound	4·5	45·0	19·4	10·4	0·9	1·1	0·2	0·2	0·1	nil	0·2	2·0	39·2	17·7
From a *M. natalensis* mound	4·4	50·6	14·7	8·4	1·3	1·2	0·4	0·8	0·6	nil	1·7	1·1	38·2	5·7

A NOTE ON DIGITARIA SCALARUM SEED

By **K. W. Harker, Animal Health Research Centre, Entebbe, Uganda**

(*Received for publication on 5th April,* 1957)

SUMMARY

Viable seed of blue couch grass has been collected. Differences have been shown to exist in the results of tests from the same seed sample but even at the lowest level of germination, the seed could be an important factor in perpetuation of the species.

INTRODUCTION

Digitaria scalarum Chiov., blue couch grass is a serious weed of cultivation. In Uganda it is probably the worst weed of cultivated plots. The deep underground roots make it extremely difficult to eradicate and during cultivation these roots have to be removed completely, otherwise any small portion left behind is capable of producing a new plant. Multiplication by seed is, however, not usually considered as a factor in propagation.

In September, 1953, an area of *D. scalarum* on an abandoned plot at Old Entebbe, was seen to be seeding profusely. Some of this seed was collected to assess the germination potential. Further collections from other areas were made in October, 1954, and January to March, 1955. In two cases the yield of seed was estimated. The result was 70 lb. per acre, which, at a rate of 1,500,000 seeds per pound, represents a seed rate of 22,700 seeds per square yard. The seeds were stored in aluminium tins and sub-samples were tested within a few weeks of collection and at six-monthly intervals.

SEED TESTING

The testing procedure was to count out 100 seed units, i.e. both full and empty glumes, on to moist sand in a petri dish. Each test was made up of ten dishes, and every day for three weeks the dishes were examined and any germinating seeds picked off and the number recorded. This method is not the officially recognized procedure, but the results are equivalent to the percentage pure germinating seed of an official test. The results of the tests are given in Table I.

It will be noted that the germination potential varies considerably. The first test always gave low results, but the percentage tended to improve with storage. The results are, however, very variable with considerable fluctuations between six-monthly tests. The variations could have been attributed to the test method. In order to try to check this, sub-samples of numbers 47 and 50 were sent to the Scott Agricultural Laboratory, Nairobi, for official tests. The results of these tests are given in Table II and should be compared with the "18-month tests" at Entebbe. The comparison indicates that there is some major difference between Nairobi and Entebbe test conditions.

TABLE 1—THE PERCENTAGE GERMINATION OF *Digitaria Scalarum* SEED (Entebbe tests)

Sample No.	First test seed 3–5 weeks old	TESTS AFTER STORAGE FOR APPROXIMATELY			
		6 months	12 months	18 months	24 months
39 . .	2·3	5·7	2·2	6·5	6·8
47 . .	5·1	43·7	19·0	78·0	
50 . .	7·4	58·4	8·9	62·6	
56 . .	0·7	2·5	1·8		
109 . .	Not tested	7·8	47·8	45·4	41·1

TABLE II—THE RESULTS OF OFFICIAL SEED TESTS

Sample	Per cent Purity	Germinating in 10 days	Germinating in 30 days	Pure Germinating seed
47 . .	74·5	9·0	25·0	18·6
50 . .	77·5	15·0	26·25	20·3
47 Scarified	74·5	8·25	31·75	23·65
50 Scarified	77·5	10·5	24·7	19·2

The test method at Nairobi is first to isolate the pure seed, then to germinate the pure seed on filter-paper at room temperature. At the Scott Laboratory, the temperature in the testing room fluctuated between 59° and 73° F. during the period of the test, whilst at Entebbe the temperature in the testting room during the "18-month test" varied between 68° and 84° F. Thus, differences in temperature might have caused the difference in germination potential. This temperature effect might also account for the variable results of the Entebbe tests. Trials at different temperatures are to be undertaken to check this effect.

In spite of the difficulties of seed testing, it is obvious from the results obtained that the seed of *D. scalarum* constitutes a serious menace to the cultivator. Even with a germination rate of 1 per cent, a single crop of seed can produce viable seed at the rate of 26 per square foot. The germination potential, however, could be much higher than 1 per cent.

The help and co-operation of Mrs. Nattrass at the Scott Agricultural Laboratory, is gratefully acknowledged.

THE BANANA WEEVIL AND ITS CONTROL

By **Paul E. S. Whalley, Department of Agriculture, Uganda**

(*Received for publication on 27th May*, 1957)

Many accounts have been published on the banana weevil (*Cosmopolites sordidus* Germar). These have varied from notes of its arrival in a country to details of life history and control measures (e.g. Jepsom (1914) Froggatt (1928), Ghesquière (1926), Leonard (1931), and Cuille (1950)). Harris (1947) gives an account of this pest in East Africa with details of distribution, life history and control measures. The present account is intended to supplement his paper.

The most important single factor which has emerged from recent investigations is that there are two, and possibly four, species of weevil which will attack living bananas in Uganda. The larvae of all these species are very similar and it is almost certain that they have been confused in the past.

Cosmopolites sordidus is the weevil which has been known for many years as a serious pest of bananas. This is the species which figures in all the papers mentioned previously. Recently, a weevil of the genus *Temnoschoita* Chevr. has been bred from living bananas. This is *T. nigroplagiata* Qued. The genus *Temnoschoita* has been known for some time from rotting banana pseudostems (Harris, quoted in Marshall, 1937). Harris (unpublished note) states that the larvae of *Temnoschoita* and *Cosmopolites* are very similar and Cuille (1950) adds a note that care must be taken to distinguish these two genera. Other species of *Temnoschoita* which have been recorded from rotting bananas in Uganda are *T. basipennis* Duviv. and *T. erudita* Duviv.

C. sordidus is now present in all areas in Uganda except for the immediate vicinity of Fort Portal (Western Province) where it is absent, and from West Nile (Northern Province) where it is extremely rare. *T. nigroplagiata* is distributed throughout the whole of Uganda, but is particularly abundant in the areas where *C. sordidus* is absent or very rare. *T. basipennis* appears to be very local and not common. Except for a specimen in our collection labelled Entebbe, 1909 (Gowdey) all the other records are from the Western Province. All the specimens have been bred from larvae found in rotting pseudostems. *T. erudita* has also been recorded in the adult state in rotting bananas in the Western Province, but no other information is available about it.

LIFE HISTORY AND BEHAVIOUR

An account of *C. sordidus* is given by Harris (1947). Briefly, the damage is caused by the larvae of the weevil tunnelling into the pseudostem and rhizome. The adult *C. sordidus* live under or in newly cut or rotting pseudostems. The female weevil either lays its eggs in the cut or rotting pseudostem or moves out to the living banana plant where the eggs are inserted single into a hole made by the rostrum. Usually, after egg-laying, which takes place at night, the female moves back to the rotting pieces of pseudostem. If for any reason the daylight arrives before they have moved, they will burrow just below the soil surface, or under the trash and remain there until the following night.

Migration of weevils into banana plantations and movements in the plantation have been studied before (Wallace, 1938, Simmonds, 1929). Measurements made at Kawanda Research Station, Uganda, on movement all support the previous findings that the weevil is very sedentary. Of 400 marked weevils released at one point in the plantation, 35 per cent were recovered over an eight-month period within a radius of ten yards of the original release point. No evidence of flight has been detected and the only times in the laboratory that it has been possible to make the weevil spread its wings were under conditions of extreme drought or in the latest stages of the influence of insecticide.

The rates of invasion of the plantations are not constant throughout the year and the invasion rate is highest during the wet season. This was also noted by Simmonds (1932).

The adult weevil lives in rotting stems where the humidity is very high; in fact the adult weevils are always moist under these conditions—a factor which has made marking, with paints, etc., very difficult. It is not known what initiates the movement of the weevil living as it does in the dark inside a rotting log.

None of the species of *Temnoschoita* are common enough locally to make comparable observations. *T. nigroplagiata* and *T. basipennis* differ in their life history from *C. sordidus* in that a cocoon is always formed round the pupa whereas in *C. sordidus* cocoon formation is very rare (Whalley, in press).

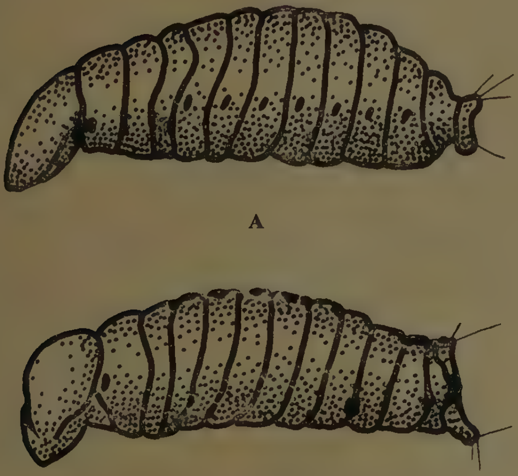
The larvae of *Temnoschoita* and *Cosmopolites* can be separated on the characters listed in Table I. (*See* also Fig. 1).

TABLE I

Temnoschoita	*Cosmopolites*
1. Head flattened dorso-ventrally.	1. Head rounded.
2. Abdomen with seven pairs of lateral spiracles.	2. Lateral abdominal spiracles rudimentary.
3. Abdomen with posterior end not abruptly truncate.	3. Abdomen with posterior end abruptly truncate.

The pupae can be separated as follows:—

Temnoschoita	*Cosmopolites*
1. Cocoon of banana fibres always present.	1. Cocoon almost always absent.
2. All ventral spines on last abdominal segment fine.	2. One pair of ventral spines on last abdominal segment thick and larger than all the others.


A

B

Fig. 1.—Larvae (lateral view)
A—Temnoschoita nigroplagiata
B—Cosmopolites sordidus

A more detailed account of the larvae is being prepared and will be published elsewhere.

CONTROL

Harris (1947) gives details of cultural control methods and an account of biological control. A recent attempt to reintroduce predators into Uganda was opposed by the local population.

Chemical control has been obtained in various countries based on aldrin. In trials in Uganda, dieldrin was preferred on account of its greater persistance. Of the insecticides tried, dieldrin 0.5 per cent dust has proved to be the easiest and safest to use under all conditions. This dust is applied lightly by a simple shaker-duster in the stools around the base of the pseudostems. Pieces of pseudostem or rhizome lying about should be split and the cut surface dusted and then placed dusted surface downward. A lot of these "poison traps" about the plantation increases the efficiency of control. As explained previously; the adult weevil lives in or under these cut stems and dusting these has proved to give a much higher kill and to clear the plantation quicker than merely dusting round the stools.

In trials round Kampala some five acres of banana plantation (some 2,500 stools) were treated at rates of from 35 lb. to 112 lb. per acre. All treatments were equally successful and the rate of application depends to a large extent on the number of stems to a stool and the number of "poisoned traps" laid down.

The cost of the treatments mentioned above varied from Sh. 17 for the lightest to Sh. 55 for the heaviest treatment per acre. The dust was still active 2½ months after application, in spite of very heavy rainstorms. While much longer will be needed to test the persistance of the insecticide, it is known that reinfestation of cleaned plantation is very slow. This treatment has resulted in almost 100 per cent clearance of adult weevil from an acre on one application of the 0.5 dieldrin dust. In the first year of treatment of a plantation two (at the most three) applications of the dust at 6 (4) monthly intervals will be needed with probably one dusting each subsequent year to deal with reinfestation.

SUMMARY

1. This paper is a supplement to that of Harris (1947) on *Cosmopolites sordidus* in Uganda.

2. *Temnoschoita nigroplagiata* is recorded as attacking living bananas.

3. Some account of the distribution of *Temnoschoita* is given.

4. An account of the migration and mode of life of *C. sordidus* is given.

5. Control measures, based on the use of 0.5 per cent dieldrin dust are recommended.

6. Almost 100 per cent clearance of plantations has been obtained over a two/three-month period with one application of dieldrin 0.5 dust.

ACKNOWLEDGMENTS

The assistance and advice of Mr. J. C. Davies, entomologist, Mr. H. D. Mubbiru and Mr. T. R. Odhiambo, of Kawanda is gratefully acknowledged. Also the help of Messrs. Kanakulya, Mabizzi, Kiboigo, Kiriggwajjo and Kibeti with the field work is appreciated. Permission to publish this paper has been received from the Director of Agriculture, Uganda.

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REVIEW

MECHANIZATION OF TROPICAL CROPS, by W. N. Bates, with a foreword by Dr. Cornelius Davies. Published by Temple Press Ltd., London, in association with *Farm Mechanization*, 1957, pp. 410, figs. 126. Price 45s.

This is an ambitious volume which attempts to fill a very large void in the technical literature of tropical agriculture. The text covers first a broad introduction to mechanized agriculture dealing very briefly with climate, soils, soil conservation, drainage and irrigation. Part II, the most valuable part of the book, deals with mechanization in tropical areas, while Part III has 15 brief chapters giving a summary of mechanization in particular crops. Inevitably the main criticism is that the subject range is too wide so that very many subjects are mentioned rather than discussed. In fact, the book would have been greatly improved if the first part had been reduced to a rather long introduction, the second part expanded to give far more technical detail, and the third part reduced to a series of notes. It is not possible in less than an encyclopaedia to cover the range attempted by the author.

As general knowledge reading for the agricultural student the book will undoubtedly take high priority in study courses. It provides a self-contained "refresher course" for the agricultural officer whose duties have kept him away from agricultural shows and literature, and the book will be widely welcomed.

For those specializing in development or research in tropical tillage and crop handling machinery, however, the book will be disappointingly lacking in detail, particularly in the brief sections dealing with individual crops.

There is a wealth of good photographs and clear diagrams, and the book is well produced and arranged with a useful index and appendices on maintenance and administration of diesel-engined tractors.

H. C. P.

NOTES ON THE BIOLOGY OF THE DORADE OR DOLPHIN-FISH (CORYPHAENA HIPPURUS) IN EAST AFRICAN WATERS

By **F. Williams and B. S. Newell, East African Marine Fisheries Research Organization, Zanzibar**

(*Received for publication on 24th June,* 1957)

The routine cruises of *Research*, the vessel of the East African Marine Fisheries Research Organization, from January, 1952, to December, 1956, in East African coastal waters, have brought to light much interesting information regarding the biology of the dolphin-fish or dorade (*Coryphaena hippurus* L.) and its relation to the prevailing oceanographic conditions. The dorade is taken in large numbers by the native fishermen in Zanzibar, Tanganyika and Kenya at certain times of the year, and is commercially valuable. The flesh soon goes soft without refrigeration and, consequently, fishing takes place close to the home port or centre of distribution.

METHODS

Multiple surface-trolling accounted for the capture of 86 of the 98 specimens taken by *Research*, and a further 48 strikes and fish lost were positively identified as dorade. The gear used for trolling in *Research* has been described in detail elsewhere (Williams, F., 1956). It suffices here to say that some 15 types and colours of lures have been trolled at speeds between four and eight knots. There appears to be no significant difference in the catching power of the lures per line hour.

Floating, baited hand-lines were used when hydrographic or deep bottom fishing stations were occupied, and took 12 dorade, but very many more were lost. Trolling with lures and live bait and floating hand-lines are used by local fishermen.

The data collected were those normally recorded on all fish taken by *Research*: total and standard length in millimetres, weight in pounds, sex and state of maturity, and stomach contents.

DISTRIBUTION AND OCCURRENCE

The surface waters trolled are from latitude 1° 40′ S., Dicks Head, Kenya, to 10° 25′ S., Ruvuma River, Tanganyika (*see* Fig. 1), the eastern boundary being a line 30 miles off shore. Of the total of 154 catches and strikes of dorade, all but 32 (20 per cent) were taken less than five miles from the shore. It must be stated, however, that more trolling was carried out in the inshore areas. It is not possible to divide the catches up into depth areas (cf. Schuck, 1951), as the position of the 100-fathom line on this tropical coral coast varies very considerably. The time of day does not seem to affect the capture of dorade, and they have also been taken at night on passage.

Fig. 2 shows the occurrence of *Coryphaena* (fish caught and strikes) each month for the years 1952–56. Although the figures for any one month are not high, they show that the capture of the dorade is limited to the months of November to June. This is borne out by catches passing through the markets in Zanzibar, Tanga and Malindi each year—the actual poundage is not available, but January to June is the main season, with maximum abundance in the period March to May. Shoals of dorade are not seen outside this period. Fig. 2 also gives the monthly figures of surface temperature and salinity, the figures having been averaged from the data for 1953 and 1954. It will be noted that the period of maximum abundance of *Coryphaena* coincides with the time of high surface temperature and low salinity.

LENGTH AND WEIGHT

Fig. 3 shows standard length plotted against weight for 64 specimens (for the other 34 specimens only total length was available). The regression or growth curve drawn through the individual data is of the usual type $W=aL^b$, where W is weight in pounds, L is length in centimetres, a the condition factor and ^{b} the regression coefficient. The curve was fitted by the method of least squares, using a logarithmic transformation (Snedecor, 1938) and the regression equation was found to be—

$$W=8.86\times10^{-6}L^{3.164}$$

Schuck (1951), using data from 18 specimens of dorade caught in North Carolina waters, calculated the regression equation to be $W=14.4\times10^{-6}L^{3.321}$, and Morrow (1954) using data from 14 specimens caught in East African waters, produced a regression equation of $W=9.82\times10^{-8}L^{3.67}$.

Table I gives the average standard length and weight of males and females as compared with those of Schuck and Morrow.

TABLE I

	All		Males		Females	
	Av. std. length	Av. wt.	Av. std. length	Av. wt.	Av. std. length	Av. wt.
EAMFRO	74·5	8·6	81·1	10·8	72·5	8·0
Schuck ..	82·7	11·4	85·7	13·0	81·2	10·6
Morrow ..	68·2	6·4	70·0	11·0	69·0	5·75

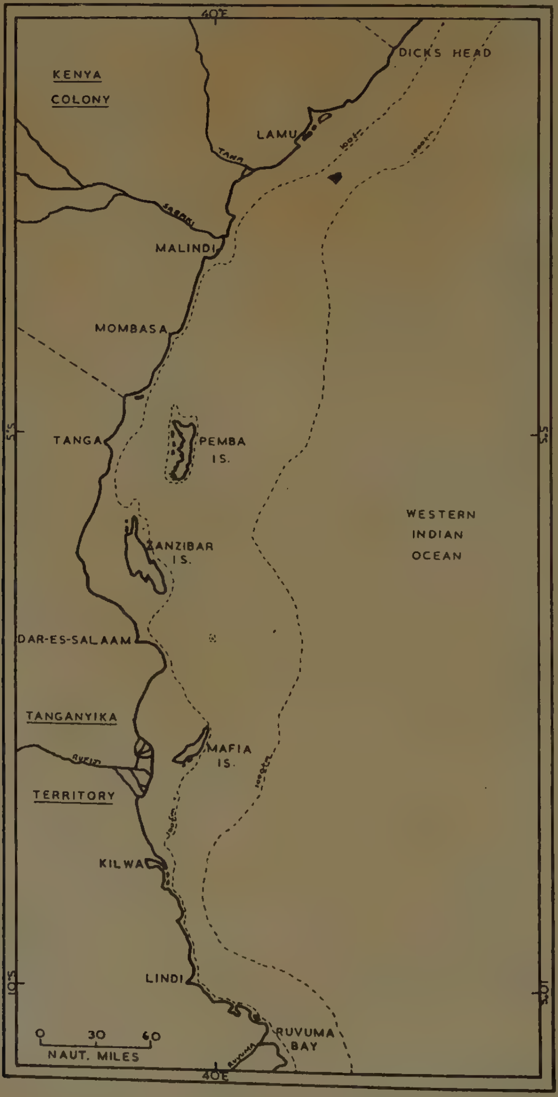

Fig. 1.—The area of operations

It was found by using the "t" test that at the 2 per cent level ($P=0.02$) males are significantly heavier than females for a given length. The calculated weights from the regression equation for standard lengths between 50 and 110 centimetres (limits of the observed data) were calculated and are shown in Table II, together with those of Schuck.

TABLE II

Standard length in centimetres	CALCULATED WEIGHT IN POUNDS	
	E.A.M.F.R.O.	Schuck
50	2·1	2·1
60	3·7	3·9
70	6·1	6·4
80	9·3	9·8
90	13·4	14·3
100	19·0	20·1
110	25·6	27·3

Our fish are lighter than those of Schuck from the Atlantic for a given length over 50 centimetres.

FOOD

Of the 98 specimens taken, 30 had no stomach contents; of the remaining 68, 25 contained unidentifiable fish remains. Thus, 43 (44 per cent) had identifiable material, the range and diversity of which was great and is here divided into five groups.

(*a*) *Adult fish.*—*Caesio* sp., *Decapterus* sp., *Atherina* sp., *Sardinella* sp., *Exocoetus volitans*, *Cypselurus* sp., Hemirhampids, Tylosurids and *Diodon* sp.

(*b*) *Larval and post-larval fish.*—Engraulids, *Holocentrus* sp., Synagnathids, acrurus and postacrurus stages of Acanthurids (probably *Naso* sp.), *Dactyloptera* sp., Gempylids, *Sphyraena* sp., *Siganus* sp., *Dasson variabilis*, Leptocephalii, Monocanthids, including *Laputa umgazi*, Aluterids, Balistids, Diodontids and *Antennarius* (?) *striatus*.

(*c*) *Macroplanktonic crustacea* including *Squilla*, Portunids and megalopa larvae.

(*d*) *Squids* and *octopi*, including the shelled octopus *Argonauta* sp.

(*e*) Turtle grass (*Cymodocea* sp.), sargassum weed and driftwood.

Most of the fish listed in (*b*) are normally found to be associated with sargassum weed (*see* "Migration Theories" below). All are feeble swimmers, shelter under the weed and are carried along with the current. In many stomachs, these fish were present with pieces of weed.

AGE AND MATURITY

No definite annuli could be observed on the sample of scales examined in the laboratory; Schuck (1951) found a similar difficulty. Otoliths were not removed.

The description of gonads was made in five stages in the males and seven in the females.

MALES—

I—*Immature.* Testes small, thread-like, no sperm. (Not seen.)

II—*Mature unripe.* Testes moderate. Sperm extruded on cutting and squeezing. Brown.

III—*Mature ripe.* Testes enlarged. lobate, sperm, extruded on cutting. Pale brown.

IV—*Mature ripe running.* As above, but sperm extruded with or without pressure to flanks. Cream.

V—*Mature spent.* Testes crinkled and shrunken, little sperm. (Not seen.)

FEMALES—

I—*Immature.* Ovaries very small, thread-like, translucent. Yellow.

II—*Mature unripe or Virgin maturing.* Ovaries small to moderate, eggs microscopic, usually translucent. Yellow.

III—*Mature ripening.* Ovaries moderate, eggs visible to naked eye, opaque. Yellow.

IV—*Mature, nearly ripe.* Ovaries enlarged and distended, eggs clearly visible, opaque. Yellow.

V—*Mature ripe.* Ovaries enlarged, distended tunica bursts easily. Some eggs transparent. Orange.

VI—*Mature ripe running.* As above, but nearly all eggs transparent. Eggs extruded on pressure to flanks. (Not seen.)

VII—*Mature spent.* Ovaries flaccid, shrunken and with residual eggs. Dark red with many blood clots.

Table III gives the record of monthly maturity states of gonads for the years 1952 to 1956.

It would appear that *C. hippurus* starts to mature below 535 mm. standard length (estimated weight 2.75 lb.). From Table III it can be seen that the female dorade gonad starts to ripen in December to January and that spawning takes place in the period March to early June. No "running" fish have been taken, but since both ripe and spent fish were caught inshore, the eggs of the dorade are presumably shed inshore—though Norman and Fraser (1937) suggested that they were propably shed in the open sea. Eggs are pelagic, as are the larvae, but neither have been taken, or at least identified, as such, in the catches of the young fish trawl and plankton nets of this organization.

TABLE III

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
(a) MALES—												
Stage I	—	—	—	—	—	—	—	—	—	—	—	—
II	—	—	2	4	2	—	—	—	—	—	1	—
III	—	—	3	7	3	—	—	—	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—	—	—
V	—	—	—	—	—	—	—	—	—	—	—	—
(b) FEMALES—												
Stage I	1	—	1	—	—	—	—	—	—	—	—	—
II	—	—	5	4	1	—	—	—	—	—	—	—
III	—	1	3	1	1	—	—	—	—	—	—	—
IV	2	3	3	9	9	—	—	—	—	—	1	—
V	2	2	—	8	12	1	—	—	—	—	—	—
VI	—	—	—	—	—	—	—	—	—	—	—	—
VII	—	—	—	5	—	—	—	—	—	—	—	—

Of the 98 specimens taken, 19 were males and 79 females—1:4. It has been stated earlier (Williams, F., 1956), that personal observation in Zanzibar fish market from 1952 to 1954 show males to females about 1:15.

Sexual dimorphism in the shape of the head was marked even in specimens of 500–600 mm. standard length.

MIGRATION THEORIES

The facts show that *C. hippurus* makes a migration into East African coastal waters between November and early June each year. During this period the fish would seem to ripen and spawn inshore (Williams, 1953), a similar migration occurring in the Seychelles Islands. (Wheeler and Ommanney, 1953, and unpublished log data).

Various tentative explanations for this periodic occurrence have been considered by us, after appraisal of all relevant data, and are presented here in the hope that they may stimulate discussion of this interesting phenomenon.

Firstly, it is possible that the inshore migration is due to an inherent instinct.

Secondly, some environmental factors may act as stimuli. One such factor could be temperature, since the dorade appears in the coastal waters here and in shallow waters around Seychelles during the period of maximum surface water temperatures (29–30° C.). It also appears around Mauritius in the southern summer (Wheeler and Ommanney, 1953), being absent in the winter when surface water temperatures are down to *circa* 24° C. In southern Japanese waters (Okada, 1955), the dorade spawns in July and August; surface temperatures (Sverdrup *et al*, 1941) in this region at that time of the year are about 28° C. Kishinouye (1923) states that "Scromboid fishes migrate north and south in Japanese waters more or less with the surface isotherms". Mather and Day (1954) give minimum water temperatures in the Atlantic for the occurrence of *C. hippurus* as 70° F. (21° C.) and for *C. equisetus* as 75° F. (24° C.), but they quote Postel (1950) as reporting that dorade appear off the West African coast only in the warm season. It should be noted that the specimens taken by Mather and Day were from stations in the open ocean from February to December. If the temperature is the governing factor, then it is feasible that in the East African region, the dorade moves north and south with the surface isotherms over the year. Fig. 2 shows that warmer water appears here during the period of dorade occurrence. This is due both to the southerly Somaliland current and the rise in temperature of the South Equatorial and East African coastal currents. Unfortunately, no catch figures are available from north of Kenya, though Copley (1951) states that shoals of dolphin fish occur in the tide rips off Cape Gardafui. The Gulf of Aden and its approaches reach their minimum surface water temperature of the year (*circa* 26° C.) from November to February. The warm surface water (29–30° C.) found in this region during the northern summer is displaced south by the north-east monsoon (Mathews, 1926), forming the Somaliland current, the dorade possibly moving in this warm water mass. It is hardly likely that the dorade migrates inshore from the open ocean in response to temperature (except as suggested below) since the surface isotherms of the Western Indian Ocean are at right angles to the coast (Sverdrup *et al*, 1941, Chart II and III, Appendix).

The dorade also appears in this area at about the time of the maximum surface salinity (November/December), but the apparent spawning period coincides with the time of lower salinities, the minimum surface salinity for the year being found during April and May on this coast.

One of us (B. S. N.) has recently shown that in East African coastal waters a vigorous increase in the plankton growth occurs during the north-east monsoon. This outburst did not begin until January in the season 1955/56, but has already begun in October of this season of 1956/57, and the variation is probably due to the varying strength and duration of the south-east monsoon from year to year. Oceanographic data collected on *Research* indicate that 1956 has seen a mild south-east monsoon. It is interesting to note that no dorade were caught in the 1955/56 season until February (though one strike occurred in November), whilst this season, 1956/57, there have been two strikes and one capture as early as November and December, so that the occurrence of dorade may be connected with the onset of the seasonal plankton outburst. The plankton growth reaches a maximum in March, declining through May until in June the oxygen and pH profiles show no active photosynthesis in the water column. Thus the period of dorade occurrence coincides with the period of greatest fertility of the coastal water.

The fact that as early as January many dorade are caught in the southernmost part of our area and that the fish is reported generally to be of ocean-wide distribution, suggests that the dorade might reach this coast

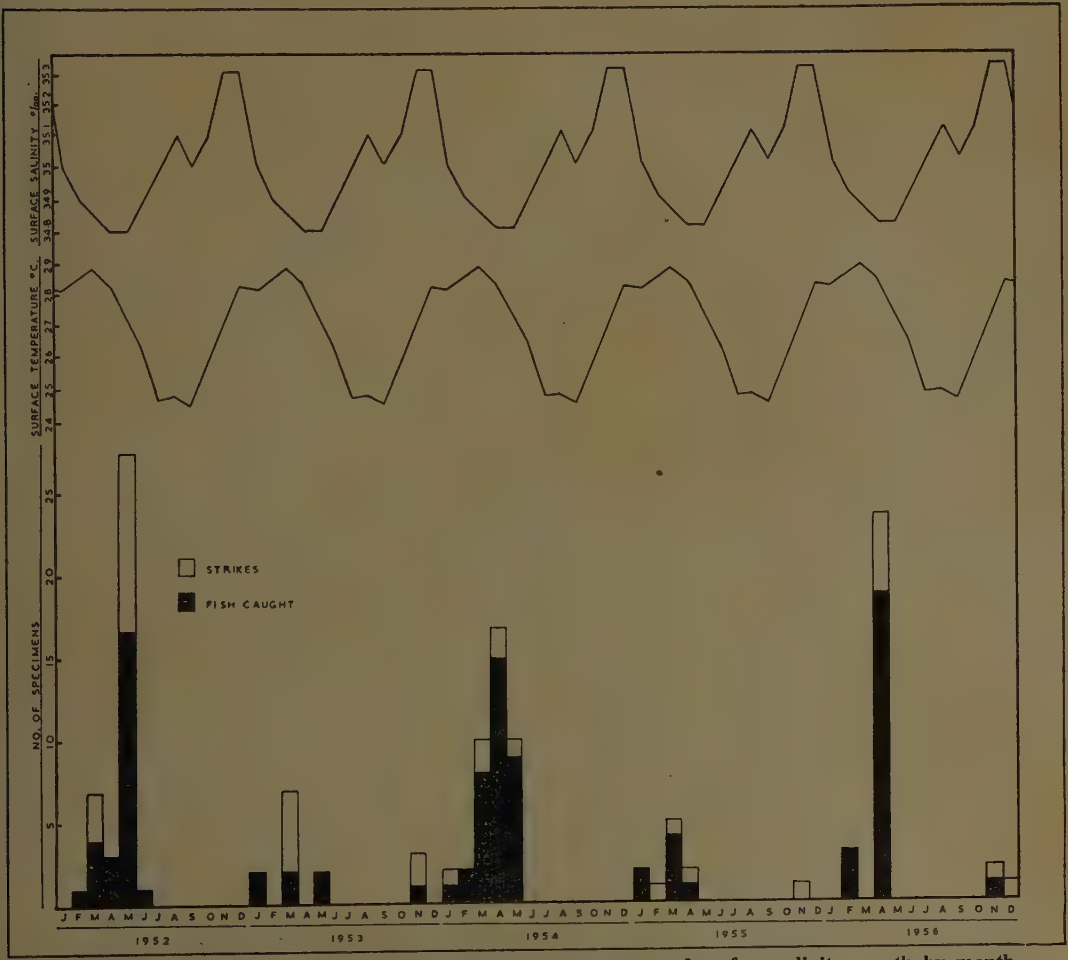

Fig. 2.—The occurrence of dorade, surface water temperature and surface salinity month by month for the years 1952–1956

with the South Equatorial current, following the warm front which develops in this current as the southern summer begins. The dorade is reported from the Comoro Islands (Fourmanoir, 1954) which are bathed by the Mozambique current, the southern leg of the South Equatorial current after it bifurcates at Cape Delgado, but unfortunately, times of ocurrence are not given.

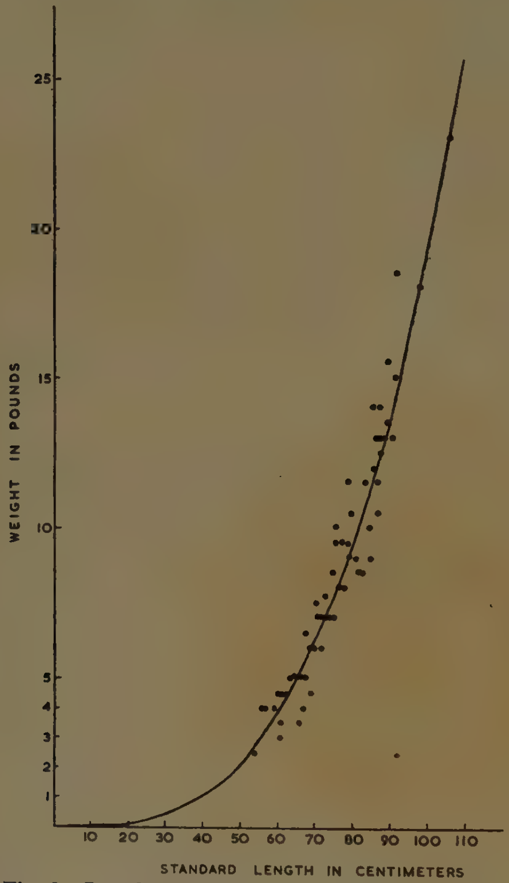

Fig. 3.—Lengths and weights of 64 dorade and their growth curve calculated from the regression equation: $W = 8.86 \times 10^{-6} L^{3.184}$

During the northern monsoon (November to April), there is a tendency for sargassum to accumulate off the coast, partly due to the east and north-east winds and partly due to the slowing-up of the surface current. Since the dorade is often found in close association with sargassum patches, there may be a connexion with its appearance near the coast and the period of maximum sargassum accumulation. An interesting note is made by Copley (1951) who describes a method of capture dependent on the habit of dorade congregating under weed, etc.—" . . . at the end of the summer dolphin appear in large shoals in the Mediterranean, and are caught by putting out large, light rafts and floating mats; the fish congregate under these and the rafts are surrounded by a net and the fish are driven into it. . . . "

It seems most probable that all these environmental factors contribute, in varying degree, to an explanation of the seasonal occurrence of *C. hippurus* since all are interlinked, no one factor being independent of the prevailing oceanographic conditions.

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BEE BOTANY IN EAST AFRICA

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(*Received for publication on* 29*th April,* 1957)

Bee botany is the study of those plants which are of importance to honey bees. Bees are dependent for their very existence on flowering plants which provide them with all their food in the forms of nectar and pollen. It is essential for the beekeeper, who wants to consider the management of bees for the production of maximum crops of honey and beeswax, to know which plants are of value to bees, where they are to be found, and when they flower. He should know those which are merely producers of subsistance for the bees, those which are capable of producing heavy yields of nectar which will enable the bees to store surplus food, and which plants result in the production of high-quality honey and which cause unmarketable honey to be produced.

It is considered that the best way of getting most of the information required is from the bees themselves. When bees collect nectar they also obtain a small proportion of pollen from the flower. This pollen has either fallen, blown or been knocked into the nectary or clings to the hairs of the bees. After the nectar has been converted into honey in the hive, the pollen remains present in the honey, which is an excellent preservative. In addition, bees collect pollen for food and store it in the combs. Clearly, if the pollen in the honey and that which is stored in the combs can be identified as to the plants of origin, we will then know which plants are of value to the bees. The relative importance will depend upon the quantities of honey containing particular pollens, not on the actual quantities of pollen because the honey from different plants contains pollen in different proportions.

In order to be able to identify the plants from which pollen has come, it is necessary to build up a collection of named pollen preparations on microscope slides. The pollens forming the collection of standards must be collected from correctly identified plants. The major part of this work has been the task of collecting pollen samples and herbarium specimens from as many plants as possible, having the herbarium specimens named, preparing and mounting the pollen samples and describing each pollen, recording the description in such a manner so that it can be picked out from the whole collection easily.

The next stage is the collection of honey samples and hive material from different areas and at different seasons, and the identification of the plants of origin. The field notes made at the time of herbarium and pollen collections together with studies of the vegetation types provide information which will be of value when bee management is considered.

METHOD

All the pollen grains studied in this work were collected from growing plants. None was taken from herbarium collections. This made it possible to study the actual conditions under which the plants occurred. Pollen-bearing material from the flowers was put into 2-inch long by $\frac{3}{8}$-inch diameter glass vials, half-filled with glacial acetic acid. The corks were numbered. Sufficient herbarium material was collected for a sheet in the Beekeeping Research Station Herbarium and with ample spare for determination purposes.

Field notes were entered on specially designed botanical record cards. The edges of the cards have a series of holes to enable the Paramount sorting system to be used. Provision was made for sorting by family, genus, reference number, vegetation type, month of flowering, province in which the collection was made and action taken. The collector entered on the front of the card the date, reference number, local name if known, the collector's initials and the description of the habitat and locality. On the reverse of the cards were entered such features of the botanical description as were required to add to those apparent in the herbarium sheet.

Back at the research station, a herbarium sheet was prepared and the remainder of the herbarium material sent with the appropriate field notes to the East African Herbarium, Nairobi, for determination. A microscope slide of the pollen sample was prepared and the pollen described. The pollen description was entered on a specially designed record card. The original reference number appears on the botanical record card, herbarium sheet, pollen slide, pollen description card and if a photograph was taken, on the negative index.

At the beginning of this work, various methods of preparing pollen slides were tried. It was found that Erdtman's method, although more complicated, produced the most satisfactory preparations for the examination of structural detail. Two features of this method that recommended themselves were the removal of plasmic material which otherwise distorted the light passing through the grain and the staining of the wall a yellowish brown which made for ease of examination in pale blue light. Previously a whole range of microscopic stains recommended by Wodehouse were tried but none gave such satisfactory results. In Erdtman's method the pollen grains are heated in an acetolysis mixture composed of nine parts of acetic anhydride to one part concentrated sulphuric acid. The grains are then washed with distilled water and soaked in a mixture of one part distilled water to one part glycerine. The mounting is done in glycerine jelly and the preparation sealed with canada balsam. Pollen taken from the legs of bees and pollen from comb was treated in the same way. The pollen from honey was extracted by centrifuge after diluting one part of honey with two parts distilled water and then prepared by the same method.

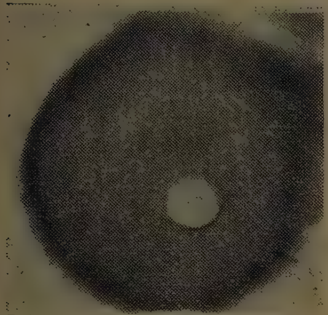
The walls of pollen grains reveal a variety of structural characteristics. There may be apertures in the walls, which may be circular or elongated. The walls are composed of different layers and the apertures in the inner layers may be of a different shape from those in the outer layers. The surface of the walls often shows markings due to the uneven nature of the surface. The layers of the walls may be of different thicknesses. Pollen grains have a variety of different shapes and sizes.

The normal optical microscope enables us to examine the characteristics of the walls of pollen grains. For this work a × 40 objective and × 11 eyepieces were normally used. Occasional use was made of a × 100 oil immersion objective to examine difficult structures. However, often it is not possible to interpret the cause of particular markings observed. As the characteristics of the pollen of any species of plant are more or less constant, it is possible to use these features in identifying the plant from which the pollen has come. In a few cases the pollens of a single family, or even of different families, are so similar that one cannot do more than name the family or group of families. Usually, however, genera or groups of genera are distinguishable, and often species can be named.

The descriptions of the pollen grains were typed on the pollen description cards. After completion of the description, the holes opposite the relevent features were punched away. These cards are designed by the author to be sorted by the Paramount system. Provision is made for the cards to be picked out by the number of apertures, type and position of apertures, characteristics of furrows and ora, shape, ornamentation, radiosymetrical shape classes, length of equatorial diameter and polar axis as well as by reference number and family.

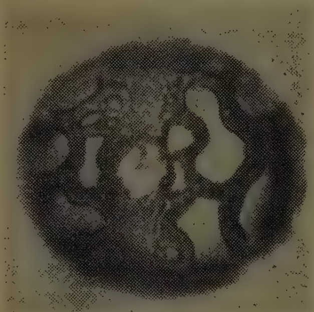
As the collection of record cards increased, it was found necessary to introduce a preliminary sorting series. This was done by the preparation of family cards. Those families whose pollen grains fall into several distinct types had a card prepared for each type. On the family card were entered all the characteristics of all pollen grains collected in that family. Thus when it was desired to identify a pollen found in honey or hive material, the family cards were sorted with the needle first. Those family cards having the characteristics required fell out. Then each family whose family card had fallen out was sorted in turn. The result might be several pollen description cards of different families each having the characteristics sought. The next stage was to examine under the microscope the slides corresponding to the cards until the pollen slide corresponding in all detail to the specimen to be identified was found. This part of the work has been simplified by the use of photomicrographs of pollen grains.

Photomicrographs illustrate the important characteristics of the pollens described. As the depth of focus is very shallow, a photograph shows only an optical section through the grain. While this has the disadvantage of not

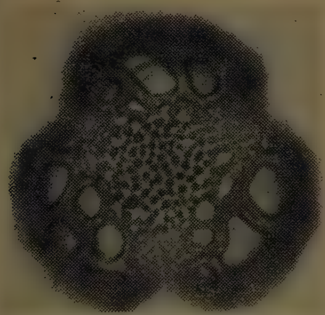


Julbernardia globiflora, Smith 14. Equatorial view

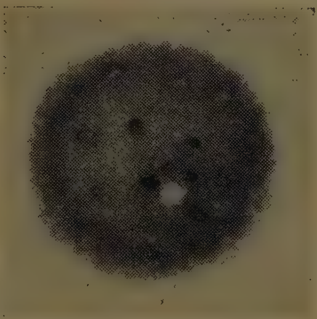
Julbernardia globiflora, Smith 14. Polar view



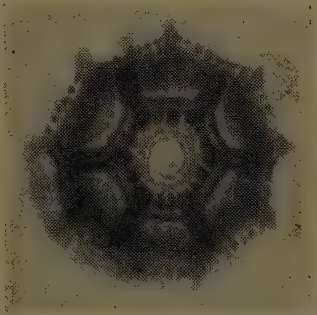
Brachystegia spiciformis, Joseph 44. Equatorial view



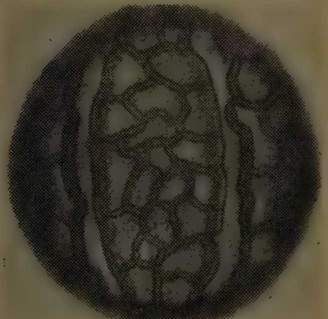
Brachystegia spiciformis, Joseph 44. Polar view



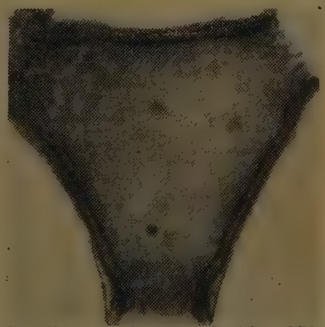
Dombeya rotundifolia, Smith 1192. Equatorial view



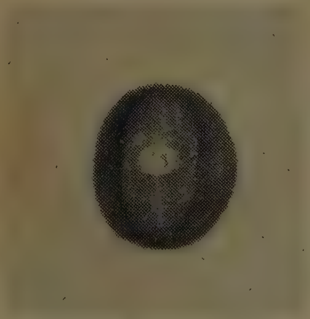
Vernonia aemulans, Smith 885. Equatorial view



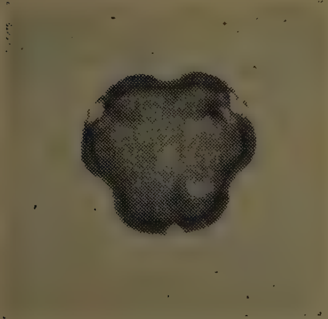
Becium obovatum, Smith 134. Equatorial view



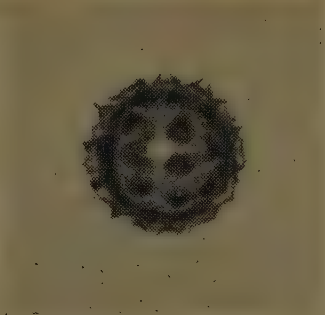
Grevillea robusta, Smith 958. Equatorial section



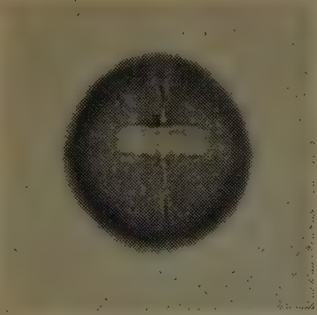
Combretum apiculatum, Smith 154. Equatorial view



Combretum apiculatum, Smith 154. Equatorial section



Bidens pilosa, Smith 4. Equatorial view



Ricinus communis, Smith 918. Equatorial view

All magnifications × 800.

showing the grain as a whole, it reveals structural details and is a realistic picture of what one actually sees through the microscope. In this respect it is considered that photographs are more helpful in identifying pollens than is the use of drawings, unless the latter are the work of a brilliant artist. The photomicrographs were taken with a Rolleiflex camera with adaptors on Kodak P.300 plates and Panatomic X 35 mm. film. The camera, microscope and lamp were set up on a home-made optical bench. The final pictures are enlargements × 800 natural size.

One thousand three hundred and seventy-two collections of pollen grains with herbarium material were made, of which 974 herbarium specimens were determined by the East African Herbarium, and the rest by the author. The pollen grains of 630 different species of plants were described and 373 photographs of the main morphological types of grains were prepared. These figures are constantly being added to by current collections.

In order to obtain information as to the seasons when the bees are able to obtain honey crops in different areas, as well as data on brood rearing, reproductive swarming, and samples for pollen analysis, a series of scale hives were established in various centres. A scale hive consisted of a Modified Dadant frame hive stocked with bees and permanently standing on a counter platform scale. A guard was responsible for maintaining the hive, reading the scale at dawn and dusk each day and preventing any interference with the hive. Unfortunately, distances being so great, little supervision was possible, and the guards failed to maintain the hives and scales properly. The failure of the guards and the depredations of the local population in search of honey rendered this part of the work of little value in most places.

Scale hives were established at Tengeru, Lyamungu and Ngorongoro to obtain data from the upland forest in coffee-growing areas. Tengeru is on the lower slopes of Mt. Meru, Lyamungu on the lower slopes of Kilimanjaro, and the Ngorongoro site enables the bees to range from wooded grassland with scattered trees below the coffee farms to the top of the upland forest on the rim of Ngorongoro crater. However, after a few months the Ngorongoro hive had to be moved and it was taken to Mto-wa-Mbu, a patch of ground-water forest near Lake Manyara at the foot of the Rift Valley wall. A scale hive was put in the Nou Forest at Mbulu to study a slightly different type of upland forest, another at Bereku in upper deciduous woodland and one at Itigi in deciduous thicket. Three scale hives to study the deciduous woodland were located near Tabora, Mpanda and Songea.

Each guard was supposed to complete an apiary record card each month showing the dawn and dusk hive weights each day with notes on the weather and bee activity. On the reverse of the cards note was to be made of the plants flowering within two miles of the scale hive.

Finally, the data obtained from field observations, collections of plants in flower and scale hive studies were summarized on ecological record cards. On these cards is shown the particulars of the locality, habitat and description of the plant community and on the reverse is recorded the floristic composition showing opposite the name of each plant whether it is a tree, shrub, herb or climber, its frequency of occurence and the month or months of flowering.

Sources of Pollen

From the examination of pollen collected from the legs of bees and from combs, the bees appear to utilize any plants that yield pollen abundantly, even the grasses which do not yield nectar. Further, the bees are dependent on the day-to-day supply of pollen for their requirements to a very great extent. The amount of pollen stored in the combs and not used almost immediately is very small. It also appears, from examination of the brood nests at different seasons of the year, that the production of brood depends upon the availability of pollen. When pollen is no longer available for collection, as happens sometimes in January in the Tabora region if there is a long break in the rains, brood rearing declines, although there may be abundant stocks of stored honey. When the dry season begins in June in the Tabora region, the trees cease flowering and the herbaceous plants dry out and are often burnt, brood rearing again declines and by July it ceases altogether. In August, however, the first of the flowers appear on the trees and brood rearing starts again. During the periods when no pollen is available, bees will collect maize or cassava flour if they can get it, and this, presumably, they feed to the brood in lieu of pollen.

The following list gives some idea of the variety of plants from which pollen is collected in the deciduous woodland areas of Tabora, Mpanda, Kahama, Kasulu and Songea, but the list is by no means exhaustive:—

Acacia spp.
Amaranthus dubius
Anacardiaceae
Aspilia-Wedelia complex
Becium obovatum
Bidens spp.
Borreria spp.
Brachystegia spp.
Cassia spp.
Cephalaria goetzei
Chlorophytum sp.
Citrus spp.
Clematopsis scabiosifolia
Combretum spp.
Commelina spp.
Compositae
Croton sp.
Cynodon dactylon
Cyperaceae
Delonix regia
Endostemon sp.
Eucalyptus spp.
Geraniaceae
Gramineae
Gynandropsis gynandra
Hymenocardia sp.
Lannea spp.
Malvaceae
Oxygonum atriplicifolium
Papilionaceae
Polygonum tomentosum
Psidium sp.
Psoropermum campestre
Randia sp.
Richardia scabra
Sesamum angustifolium
Sida cordifolia
Solanum sp.
Sporobolus pyramidalis
Stylosanthes bojeri
Syzygium spp.
Tridax procumbens
Triumfetta spp.
Vernonia spp.
Waltheria indica

SOURCES OF NECTAR

Pollen analysis has been carried out so far on 80 samples of honey. In most samples, the pollen grains present are limited to a few species, even when the honey sample represents the surplus stored by the bees throughout the year. In some samples, however, there is a large variety of pollen grains, but these do not necessarily represent the plants valuable for honey production. This is apparent from the presence of grass pollen in some honey. In such cases, the pollen grains in the honey are not only those of the plants from which the nectar was gathered, but also those of the plants from which the bees collected pollen loads. Their presence in the honey is explained by the practice of African beekeepers of removing not only the honeycombs from the hive, but also those containing stored pollen. These being pressed all together result in the inclusion in the honey of much pollen material which was not there originally. Pure honeycomb contains a very small amount of pollen, whereas some of the samples of honey obtained from African beekeepers were visibly cloudy with it. It would therefore give an entirely false picture if the relative proportions of pollen in such a honey sample were to be regarded as indicating the relative importance of those plants as nectar producers. The only honey samples which can be regarded as providing useful data as to their origin from pollen analysis are those which are known to have been obtained from pure honeycomb. Even then the results will be weighted by the structure of the flowers and the abundance of pollen produced by each species. This makes pollen analysis far from being exact, and a large number of carefully collected samples of honey from pure honeycomb are required before any conclusions can be reached.

The Deciduous Woodland of Western Province

Forty-eight honey samples from the deciduous woodland have been examined and the principle sources of nectar have been identified as follows:—

Julbernardia spp., Caesalpiniaceae, *J. globiflora* in most of the area, *J. paniculata* in Kibondo, Kasulu and west Mpanda districts, and *J. unijugata* along the rivers of Kigoma district and the Tongwe area of Mpanda. *J. globiflora*, and *J. paniculata* are one of the most abundant trees in the deciduous woodland. They may start flowering in some localities as early as March, but the honey flow begins at the end of April, reaches a peak in the middle of May and ends at the beginning of June. Should the rains end early the flowers of these trees may shrivel and fall without yielding nectar. Some years a good honey flow failed to materialize due to damage to the trees caused by caterpillars.

The honey produced is of very high quality, extra light amber in colour and of a very pleasant flavour. This was identified in 26 samples. Over 50 per cent was present in six samples and over 20 per cent in 13 samples.

Brachystegia spp., Caesalpiniaceae. *B. spiciformis* is to be found throughout the woodland and is abundant. *B. longifolia* is common and *B. boehmii* is local. *B. spiciformis* may start flowering in some areas in the middle of August, but all three species flower mainly in September and October. The ability of these trees to flower appears to depend on there having been an adequate rainfall the previous season.

The honey has not been found from *Brachystegia* alone, as other nectar-yielding plants flower at the same time, but the indications are that it is strongly flavoured and medium amber in colour. It appears in 20 samples, over 50 per cent in two and over 20 per cent in 12.

Lannea spp., Anacardiaceae. Common shrubs and small trees throughout the woodland. Yields nectar heavily in the early morning and late evening. Flowers August to December. Usually found mixed with *Brachystegia* or *Combretum* or both. The indications are that it is light amber honey of mild flavour. Occurs in 17 samples, more than 20 per cent in seven.

Combretum spp., Combretaceae. Common shrubs and small trees of many species. May include *Terminalia* spp. which have similar pollen but are less common. Flowers from August through to November in the woodland. No pure samples have been seen but indications are that like *Lannea* the honey is light amber or lighter and of mild flavour. Occurs in 14 samples, of which five have it more than 20 per cent. It is prominent in two samples of white honey, occurring more than 20 per cent in one of them.

Leucas spp., Labiatae. Common herbs flowering April to June. Occurs in 12 samples, more than 20 per cent in four, which are light amber and extra light amber, and more than 50 per cent in one sample which is white.

Bidens-Aspilia-Wedelia group. Compositae. The pollen of these genera are very similar and they are common throughout the woodland areas. They flower from November to June and are an important source of pollen for the bees. They occur in 14 of the samples, more than 20 per cent in four, but there are no indications as to the colour or flavour of the honey.

Vernonia aemulans, Compositae. A common herb, particularly on abandoned cultivation. Flowers from February to June. Occurs in six samples, more than 20 per cent in one.

Pollen analysis, scale hive recordings and field observations have provided the following conclusions with regard to the deciduous woodland areas of Western Tanganyika:—

Main honey flow from the end of April until the beginning of June from *Julbernardia globiflora* or *Julbernardia paniculata* according to locality, and may be supplemented by *Leucas* spp. and, in the case of hives near cultivated areas, there may be some Compositae.

Secondary honey flow starting about the middle of August, but may not develop fully until the end of September or even the end of October. May finish at the end of October or may carry on until the end of December. Mainly from *Brachystegia* spp. strongly supported by *Lannea* spp. and *Combretum* spp.

Pollen obtained from numerous herbaceous plants from November to May. If there is a severe break in the rains in January, there may be a shortage of pollen and nectar at this time.

Period of rest occurs in the dry season during July when there is no nectar or pollen available and brood rearing ceases.

Reproductive swarming takes place during October and early November and again between March and early May. Migratory swarms usually occur in July or August.

Upland Wooded Grassland and Upland Grass-Grassland

So far as we have few samples from this type of vegetation. The honey from such areas appears to be of excellent quality, being extra light amber or white, granulates quickly and finely and has a fine flavour. In two samples from Kasulu, *Eucalyptus* sp., Myrtaceae, occurs more than 50 per cent in one and more than 20 per cent in the other. *Vernonia aemulans,* Compositae, is present in both, more than 20 per cent in one. The *Bidens-Aspilia-Wedelia* group, Compositae, is represented in both and *Protea-Faurea* type, Proteaceae, occurs in one.

A sample from Ufipa was composed mainly of herbs of the upland grassland with some trees as follows:—

Becium obovatum, Labiatae—more than 20 per cent.

Dyschoriste albiflora, Acanthaceae.

Hypoestes sp., Acanthaceae.

Oxygonum atriplicifolium, Polygonaceae.

Bidens-Aspilia-Wedelia group, Compositae.

Sapinidaceae, Cyperaceae, Liliaceae.

Erythrina abyssinica, Papilionaceae.

Dombeya rotundifolia, Sterculiaceae.

Myrtaceae.

From Mbulu was obtained an extra light amber sample composed of over 80 per cent *Eucalyptus* sp. and the rest mainly *Lantana* sp.

An extra light amber sample from Lindi district had more than 90 per cent *Dombeya rotundifolia.*

Deciduous Thicket, Itigi and Manyoni Area

Scale hive and field observations indicate that the main honey flow in the Itigi thicket occurs between December and March, probably reaching a peak in February. The most important plant for nectar appears to be *Combretum trothae,* Combretaceae, which is abundant through the thicket. This plant does not flower in all parts of the area at one time, flowering appears to be staggered through the season, large patches covering several square miles presenting a mass of blossom. The honey is light to extra light amber.

Acacia Wooded Grassland and Bushland in the Dry Central Areas of Tanganyika, Dodoma and Kondoa Districts, and Machakos District of Kenya

The three samples from these areas contain a fairly large variety of pollen grains, mostly of herbs of Labiatae, Acanthaceae, Compositae, Convolvulaceae and the trees *Acacia* spp. Mimosaceae, and *Dombeya rotundifolia,* Sterculiaceae. No data are available on the periodicity of the honey flows. The honey is mainly light amber and the samples contained a large proportion of pollen which spoilt the flavour.

Upland Dry Evergreen Forest

Observations were made at Lyamungu on the lower slopes of Kilimanjaro, at Tengeru on the lower slopes of Mt. Meru, at Ngorongoro, and in the Nou Forest of Mbulu District. The main honey flow takes place in November–December and the honey is of high quality, extra light amber and good flavour. The secondary flow is during July–August, the honey obtained in this period being dark amber and of very strong flavour.

A sample of extra light amber honey from Tengeru collected in November–December contained 50 per cent of what appeared to be *Phytolacca dodecandra,* Phytolaccaceae, but the pollen of this plant is almost identical to that of *Olea hochstetteri,* Oleaceae. The other important componant was *Grevillea robusta,* Proteaceae, 20 per cent.

Two samples of dark amber strongly flavoured honey collected in June–July at Tengeru contained the following pollen grains:—

	(1) *Per cent*	(2) *Per cent*
Eucalyptus sp. Myrtaceae ..	26	30
Ricinus communis, Euphorbiaceae	7	31
Croton macrostachys, Euphorbiaceae	18	1
Triumfetta rhomboidea, Tillaceae	3	20
Compositae	13	6
Cyperaceae	9	—

Of two samples from Oldeani, one was dark amber but with a reasonable flavour and contained a wide variety of pollen grains, including *Coffea arabica, Grevillea robusta, Albizia* sp., *Eucalyptus* sp., and *Vernonia* sp. The other, medium amber and with a fairly good flavour contained *Coffea arabica,* 66 per cent, and *Grevillea robusta,* 33 per cent.

Upland Rain Forest

Five samples from South Kinangop, Kenya, which were of excellent flavour and extra light amber to white in colour, each contained *Dombeya* spp., Sterculiaceae, over 50 per cent in one and over 20 per cent in three. *Hypericum* sp., Hypericaceae, appeared over 20 per cent in two of these, and a pollen which may be *Olea* sp. occurred in three of these samples, over 50 per cent in one of them.

SOURCES OF OBJECTIONABLE HONEY

Two dark amber strongly flavoured honeys were found to contain *Elaeis guineensis,* Palmae, the plant from which red palm oil is obtained. The grains appeared over 20 per cent in a sample from Kigoma and over 50 per cent in a sample from Tabora town.

Two light honeys of unpleasant flavour contained *Agave sisalana,* Agavaceae (Sisal), over 20 per cent in one from Tumbi, Tabora District, and also over 20 per cent in the other from a sisal estate at Kilosa. Owing to the structure of the flowers of sisal, the possibilities of the bees bringing much pollen back with the nectar are slight, and the actual percentage of sisal honey in these two samples is considered to be very much higher than is indicated by the pollen content.

Manihot glaziovii, Euphorbiaceae (Ceara Rubber), has a reputation for producing unpalatable honey. It is considered that it is responsible for the bitterness of a sample from Luagala Mission, Newala District.

Ricinus communis, Euphorbiaceae (Castor Oil Plant), appears in three dark amber strongly flavoured samples, the two dark ones from Tengeru and another from Newala; but in this latter, large Graminae grains appear over 20 per cent and in yet another from Newala, also dark amber and unpalatable, they appear 100 per cent. This gives rise to the possibility of the presence of large quantities of honeydew from sugar cane.

More Honey Samples Needed

We still have a very great deal to learn about the honey plants of Tanganyika, but the foundations for this work have been laid. Samples of honey, about two ounces, taken from honeycomb free from stored pollen, and labelled with the date and locality of collection, and the collector's name and address, would be accepted most gratefully by Dr. F. G. Smith, P.O. Box 62, Tabora, Tanganyika, who will be pleased to send the collector particulars of the plants of origin as indicated by pollen analysis.

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REVIEW

Weed Control Handbook, 1957. Obtainable from the British Weed Control Council, 86, Strand, London, E.C.2. Price 5s. post free.

Previous editions of the *Weed Control Handbook*, produced by the British Weed Control Council, have had a wide circulation among farmers and others concerned with using herbicides and arboricides in the United Kingdom. The 1957 edition has been extensively revised and enlarged and is likely to be even more popular. It gives all the essential information on the well-established methods of weed control practised in the U.K., and also contains a great deal of up-to-date information on the ever-expanding range of new chemicals being tested as herbicides in various parts of the world.

Although the booklet deals specifically with the use of herbicides under temperate conditions, much of the information it contains will be useful to those interested in chemical weed control in East Africa. Chapter I, for instance, which contains notes on the weed-killers commercially available in Great Britain, is of more than local interest, as are also Chapter IV, "Recommendations for the non-selective use of herbicides"; Chapter V, "The application of herbicides"; Chapter VII, "New herbicides" and Chapter VIII, "Properties of herbicides".

The uitility of the chapters dealing with specific recommendations for using chemicals in various crops and against specific weeds is more limited. Nevertheless the recommendations contained in the sections on grassland, lawns and sports turf, and the control of acquatic weeds are in line with East African experience. Some of the uses for herbicides mentioned, such as the use of mineral oils for controlling weeds in umbelliferous crops including carrots and parsnips and conifer nurseries, have not yet been tested in East Africa, but may well be found to be valuable.

The general information on spraying cereals with selective weed-killers is also of value, but care should be taken in applying the detailed recommendations to cereal crops growing in East Africa, where the varieties are generally different and where the growing conditions may make them more suceptible to damage. It can be assumed that chemicals listed as "not recommended" for certain crops in Britain are also unsuitable for those crops in East Africa, but for suitable treatments it is advisable to follow local recommendations. It should also be noted that some of the crops and weeds which, in East Africa, have the same name as crops and weeds in Britain are different botanically and may react differently to chemicals. Beans in East Africa, for example, are different to field beans in Britain. Couch grass, campion, cleavers and nettles also refer to different species in East Africa though charlock, black bindweed, spurrey, datura, bracken and others appear to be the same. The ubiquitious Macdonaldi (*Galinsoga parviflora*) is the same species as the weed called Gallant Solider in Britain.

The general principles of controlling woody vegetation given in Chapter III, Section II, are applicable to East Africa though, with the exception of brambles, the species encountered here are very different.

Until such time as a handbook to weed control methods specially prepared for use under local conditions can be produced, this booklet will continue to be of considerable value to anyone concerned with using weed-killers in East Africa: it is intended to continue revising it annually. G. W. I.

THE NOCTURNAL REDUCTION OF DISSOLVED OXYGEN IN DAMS

By B. S. Newell, E.A. Fisheries Research Organization, Jinja, Uganda

(*Received for publication on 6th May,* 1957)

In 1953 and 1954 East African Fisheries Research Organization investigated seven dams in the Ankole District of Uganda. The temperature and oxygen data obtained have been discussed by Fish (1955). Four of these dams had been stocked with *Tilapia,* but in only one dam did the fish establish themselves. This dam was the most thoroughly oxygenated of the four. Fish discusses the various factors affecting the oxygenation of small natural bodies of water and points out that an adequate sub-surface plant population, freedom from water-lily cover and exposure to wind are each and all important.

The samples analysed by Fish were collected only during the day, so that his data give no indication of the diurnal range of oxygen in these dams. Diurnal fluctuation of oxygen content (the "diurnal pulse") in isolated bodies of water was first observed by Morren and Morren (1841) and is due to the alternation of oxygen production by photosynthesis during the day and oxygen consumption in respiration by night. The oxygen maximum for the 24-hour cycle occurs just before dark in the tropics (Vaas and Sachlan, 1953) and usually just after sunset in temperate regions (Whitney, 1942). The oxygen minimum occurs at dawn in both cases.

The diurnal variation in oxygen content is accompanied by a diurnal change in pH, carbon dioxide content and temperature (Whitney, 1942, Shilo and Shilo, 1953, and Vaas and Sachlan, 1953). Whilst the diurnal temperature change in temperate regions is small, in the tropics large fluctuations occur, and Vaas and Sachlan were able to show that nocturnal cooling in a shallow fish-pond in Indonesia was sufficient to produce a temperature inversion in the pond overnight. Furthermore, Talling (1955), when recording temperatures and oxygen content of the water column in Pilkington Bay, Lake Victoria, over a period of 48 hours, found that the water column of eight metres depth became isothermal overnight. In a pond where the bottom water is poorly oxygenated (a frequent occurrence) this nocturnal mixing should aggravate the normal overnight fall in oxygen content of the surface water, so that a pond which appeared by day to be adequately oxygenated to a reasonable depth might, in extreme cases, become anoxic throughout, during the night.

It was decided that an investigation of this problem might provide valuable information on the suitability of various ponds for stocking with fish fry, and by courtesy of the manager of Jamal Walji, Uganda Estates Limited, we were able to utilize the fish-pond on their estate for our experiments.

This pond is roughly semicircular in shape with a road running the length of the straight side. Half-way down this side is a sluice-gate used for draining the pond. The programme adopted was to take samples from surface, mid-depth and bottom at dusk, dawn and at intervals during the day. Table I shows the results obtained from oxygen analyses and temperature measurements on samples collected immediately adjacent to the sluice, where the water was 2½ metres deep.

It will be noted that there is a difference of four days between the dawn samples and those

TABLE I

Date	11–3–57		12–3–57		16–3–57					
Time	16.30		06.45		08.10		14.30		16.45	
	T°C.	O_2p.p.m.	T°C.	O_2p.p.m.	T°C.	O_2p.p.m.	T°C.	O_2p.p.m.	T°C.	O_2p.p.m.
Surface	23·5	3·3	22·0	0·1	24·0	1·60	27·5	3·4	28·5	4·0
Mid-depth	—	—	—	—	23·5	0·7	25·0	1·3	25·0	1·6
Bottom	22·5	Nil	22·0	Nil	22·4	Nil	23·5	Nil	23·5	Nil

following them in the table. This does not affect the main argument and Table I shows clearly a diurnal cycle in temperature and oxygen content in the pond with complete overturn on the night of the 11th. Complete mixing of the water column may not occur every night, but the days preceding 16th March were bright and sunny so that it may be presumed that a temperature gradient of similar magnitude to that of the 16th (i.e. 5° C.) was developed on the afternoon of the 15th. Yet by 08.10 hours on the morning of the 16th (when the pond had been exposed to the sun for nearly an hour) the temperature gradient was only 1.6° C.

The pond has an approximately semi-circular basin extending from the dam wall and is surrounded by a shallower fringe. On 16th March samples were also taken at surface, mid-depth and bottom in this basin opposite and about ten yards from the sluice. The diurnal changes in temperature and oxygen content paralleled those at the sluice, except that the mid-depth (1 metre) oxygen values were lower, and one bottom sample gave off hydrogen sulphide when acidified. The oxygen and temperature changes are shown in Table II.

TABLE II

	08·25 hrs.		16·35 hrs.	
	T°C.	O_2 p.p.m.	T°C.	O_2 p.p.m.
Surface.. ..	24·0	1·35	28·0	4·00
Mid-depth ..	23·5	Nil	25·8	3·15
Bottom.. ..	22·4	sulphide present	23·5	Nil

Despite this nocturnal deoxygenation of the water column in the basin and sluice zone, the stocking of the pond has been quite successful; the reason for this seems to lie in the presence of extensive shallow margins to the pond. It was noticed that a steady wind drift existed across the pond roughly parallel to the straight side, and when samples were taken at the windward and leeward ends of the pond at 17.00 hours on 16th March, it was found that whilst a sample from the windward end had a temperature of 26.8° C., a sample from the leeward end had a temperature of 28.8° C. The oxygen values were 2.2 p.p.m. and 3.1 p.p.m. respectively.

This indicates an accumulation of warm, oxygenated surface water towards one end of the pond, a phenonmenon which seem to be extremely important, for on both occasions when the pond was visited in the early morning, most evidence of fish life was seen at the leeward end of the pond, except for a few small *Tilapia* fry which could be seen at the surface of the water along the road edge. Evidence from the estate staff supports this as they catch large *Tilapia* almost entirely at the leeward end of the pond. (Two otters were seen hunting fish at this end of the pond on the morning of the 16th.) Netting or lining along the road edge of the pond or in the windward corner produces only a few small fish. Coupled with this was the observation that the water at the leeward end of the pond is quite clear, whilst that at the windward end tends to be dark and cloudy.

Yashouv (1956) has recently described the detrimental effects of low oxygen content on fish in ponds, having shown that nocturnal reduction of oxygen causes not only cessation of growth, but even loss of weight in the fish.

The increase in dissolved oxygen in the pond during the day would seem to be due entirely to phytoplankton activity for there is no evidence of sub-surface vegetation. In fact, the bottom over most of the pond consists of black smelly mud strewn with blackened debris (bamboo sticks, twigs and reeds).

In the light of the above data, the importance of exposure to the wind and freedom from water-lily cover (as suggested by Fish) becomes even more obvious. It would seem that the ideal dimensions of an artificial fish-pond should provide the maximum surface area for wind access and light penetration coupled with the minimum depth of water necessary to provide adequate shelter for the fish.

SUMMARY

Investigation of a dam on the Jamal Walji Estate near Jinja, shows that not only does a diurnal fluctuation of oxygen content occur due to alternation of photosynthesis and respiration, but that nocturnal cooling of the surface water may produce overturn of the water column, which denudes the surface water of oxygen.

It is suggested that artificial fish-ponds should combine maximum surface area with the minimum depth compatible with maintenance of fish life.

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REVIEW

DER TEE, by Otto F. Schleinkofer. Second Edition. 1956. Published by Cram, de Gruyter & Co., Hamburg. London price, 22s.

This is the second edition of a book first published in 1924, which sets out to give the actual or potential tea consumer in Germany a better understanding of the background of the beverage. It purports first to give a short outline of the botany, chemistry and pharmacology of tea.

The account of tea chemistry has not been revised and is quite out of date. Caffein is referred to as Theine throughout. Nothing whatever is said of the almost complete elucidation of the nature of tea polyphenols ("tannins") which has resulted from the work of Bradfield, E. A. H. Roberts, and others during the past 12 years or so; nor of the Ceylon work on the oxidative enzyme system which is concerned in tea fermentation.

Out-dated ideas of the taxonomy of the tea plant are still put forward; Assam and China tea are not now regarded as distinct botanical species, and the accepted correct name of the tea plant is *Camellia sinensis* (L.) O. Kuntze.

There is some unconscious humour in the short note on the pharmacological action of tea. Caffein is stated to differ from alcohol in that its stimulating action is not followed by paralysis. The danger limit of consumption is put at about 35 cups a day; however, the author's tea seems to be on the weak side, since in the foreword he put the number of cups brewed from half a kilo at about 500! And who was the 120-year-old Englishwoman who, during the last 45 years of her life, drank up to 40 cups of black tea daily?

A longer section of the book deals with the history of tea from its roots in Chinese mythology to the present day. The reviewer wishes here only to refer to the short section (pp. 43–44) on Africa. About tea planting in Natal the author states that since 1911, when Indian regulations limited coolie immigration (*Kuli-Einwanderung* [*sic*]) to South Africa, rising costs have limited development of tea cultivation and even caused a reduction in area. In fact, since 1948, tea has been altogether abandoned and replaced by sugar, the main crop of the district.

In the paragraph on East Africa occurs the following extraordinary statement: "A serious obstacle to the further development of African tea cultivation is the problem of labour employed. The leaves of the tea bush—hypersensitive to taints—are readily affected by the smell of the negroes, which smell is very offensive to every European (*Wurden durch den dem Neger anhaftenden, jedem Europäer widerstrebenden Geruch stark beeinträchtigt*) and consequently the value of the tea is seriously reduced. Only by the employment of Chinese and Malayan labourers was it possible to achieve the present-day quality of [African] tea".

The reviewer once heard this canard in Tanganyika (whence, in German days, it possibly originated.) Anyone having the slightest acquaintance with current tea production in East Africa knows that this paragraph is disgraceful nonsense. Many thousands of Africans of all tribes are employed in tea operations, from plucking to the final sorting and packing under conditions of employment comparable with any in the territories.

The book could be criticized in even greater detail, but enough has been said to show that it cannot be recommended. If this is the best that can be done to foster tea consumption in Germany, the Tea Bureau might consider sponsoring a translation of Harler's book.

R. C.

THE PERSISTENCE OF INSECTICIDES DEPOSITS APPLIED TO THE BARK OF COFFEE TREES (COFFEA ARABICA)

I—DDT DEPOSITS

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(*Received for publication on 7th June, 1957*)

A major pest of coffee trees in the Kilimanjaro area of Tanganyika is the white coffee borer (*Anthores leuconotus* Pasc). One possible method of control is to treat the coffee tree trunks with DDT or other persistent insecticides. Experiments are described in this paper which were carried out to obtain accurate information on the persistence of DDT deposits.

METHODS

Three experiments were carried out using DDT formulations. In the first, a 2 per cent DDT emulsion was prepared by diluting a 25 per cent DDT miscible oil (manufactured by Plant Protection Limited) with water. The trunks of coffee trees were then sprayed to run-off over a length of about 2 ft. using a hand-sprayer. Single stems of multiple-stem trees were used, the minimum diameter of the lower part of the stem being about 1.5 in. The deposits were sampled by cutting out 12-in. sections from the sprayed portions at various time intervals (usually every four weeks). Six specimens were usually taken at each sampling time, the trees to be cut being chosen at random.

In the second experiment the formulation was prepared by dissolving 35 g. of resin (supplied by Petro-chemicals Limited) (15-9/LP) in one litre of the 25 per cent DDT miscible oil. The product was diluted with water to give a 2 per cent DDT emulsion, and this was sprayed on the coffee trees as in the first experiment. The deposits were sampled as before at various time intervals.

The third experiment arose out of the results obtained in the first two experiments. Thirty coffee tree stems were selected and 6-in. lengths were sprayed with the 2 per cent DDT emulsion as in experiment 1, but the bark above and below the sprayed portion was covered with plaster tape to a length of about 8 in. in each case. The boundary between the treated and untreated portions was bound with sellotape to reduce contamination of the covered portions by run-off from the treated portion. The protective tape was removed immediately after the spraying; three specimens were taken from each stem, the 6-in. length which had been sprayed with the emulsion, and the adjacent upper and lower 6-in. sections. Samples were taken at various time intervals after the treatment.

CHEMICAL ANALYSIS OF THE DEPOSITS

An attempt was made to determine the amounts of DDT (*a*) on the surface of the bark, (*b*) in the bark, (*c*) in the bast, and (*d*) in the wood. The specimens were first washed with light petroleum (b.p., 60–90° C.) to remove the surface deposit: the solvent was applied in the form of a fine jet and the washings collected, about 100 ml. of solvent being used for each specimen. The bark was then split off as completely as possible using a scalpel; the green bast (cambium) was removed likewise; and finally the upper surface of the wood was scraped off using a knife. By this means each stem was divided into four specimens, the purpose being to determine, if possible, the depth of penetration of the DDT emulsion into the coffee tree stem.

The solvent was removed from the surface washings by distillation; the other three specimens for each stem were extracted in Soxhlet extractors for eight hours using light petroleum. The DDT in the residues from each specimen was determined by the hydrolysable-chlorine method.

Preliminary experiments were carried out to determine the efficiency of the washing technique. Logs of coffee trees were sprayed with a DDT suspension (mean particle size, 15) to give a surface deposit only, and it was found that 91–94 per cent of the DDT was removed by 50 ml. of the petroleum ether, and that the residue of DDT was negilgble after another washing with 50 ml. of solvent.

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* Now with Royal Technical College of East Africa.

It is apparent that the surface deposit is removed by this technique. However, the possibility of contamination of the surface deposit by simultaneous extraction of some of the DDT in the bark was also investigated. Specimens which had been sprayed with the emulsion were allowed to dry and then washed with successive 50 ml. portions of the solvent. It was found that the first 50 ml. contained amounts of DDT of the same order as in the first preliminary experiment, but that the successive portions after that also contained small amounts of DDT, presumably resulting from extraction of DDT from the bark. In practice, therefore, this technique will only give the approximate amounts of DDT in the surface and in the bark, but the experimental errors are considered to be less than 10 per cent.

Results

The total DDT content (in mg./sq. ft.), the surface deposit and the DDT present in the bark for experiments 1, 2 and 3 are shown in Figs. 1, 2 and 3. The cumulative rainfall for the duration of the experiments is also given. The total DDT content of the upper and lower sections adjacent to the sprayed sections of experiment 3 are given in Figs. 4 and 5.

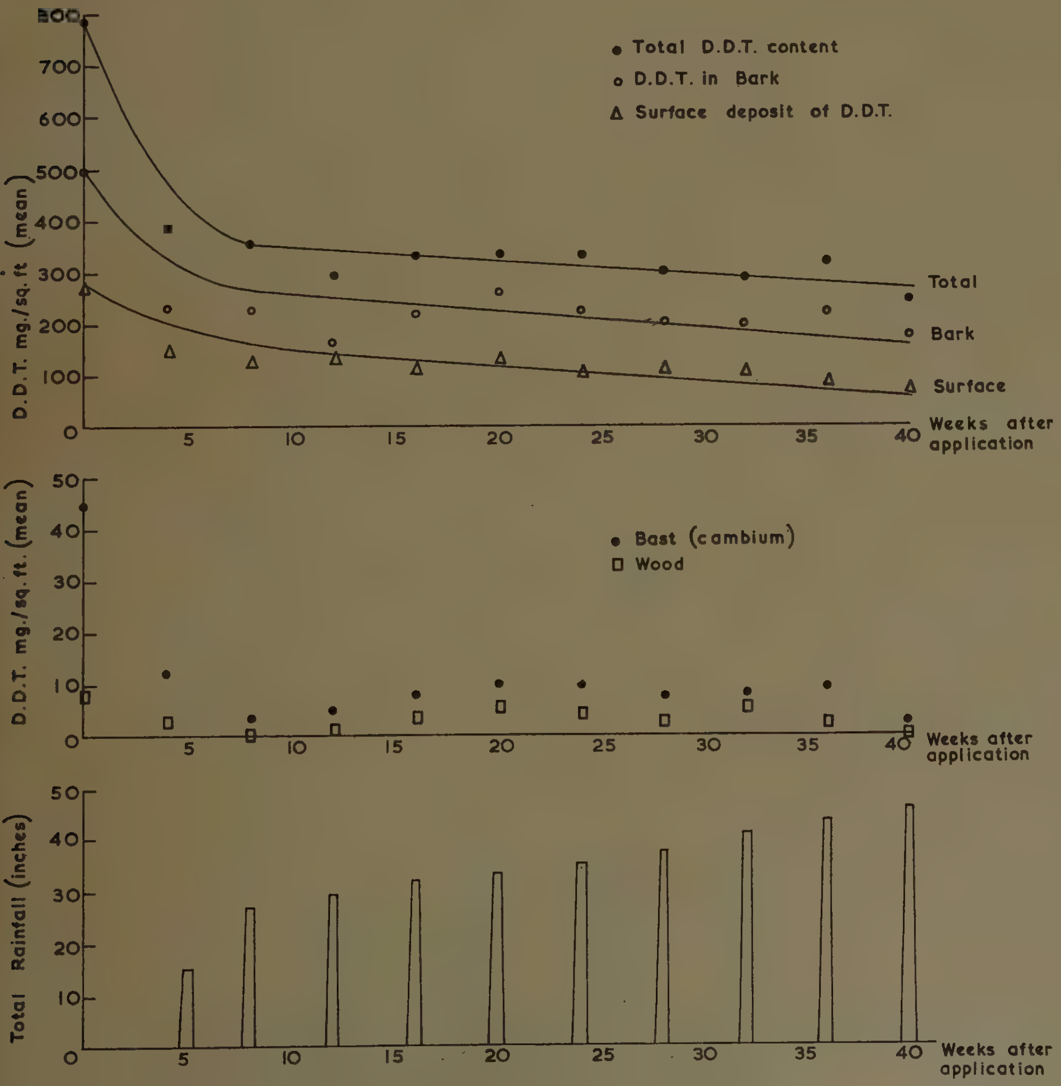

Fig. 1.—D.D.T. emulsion only (Experiment 1)

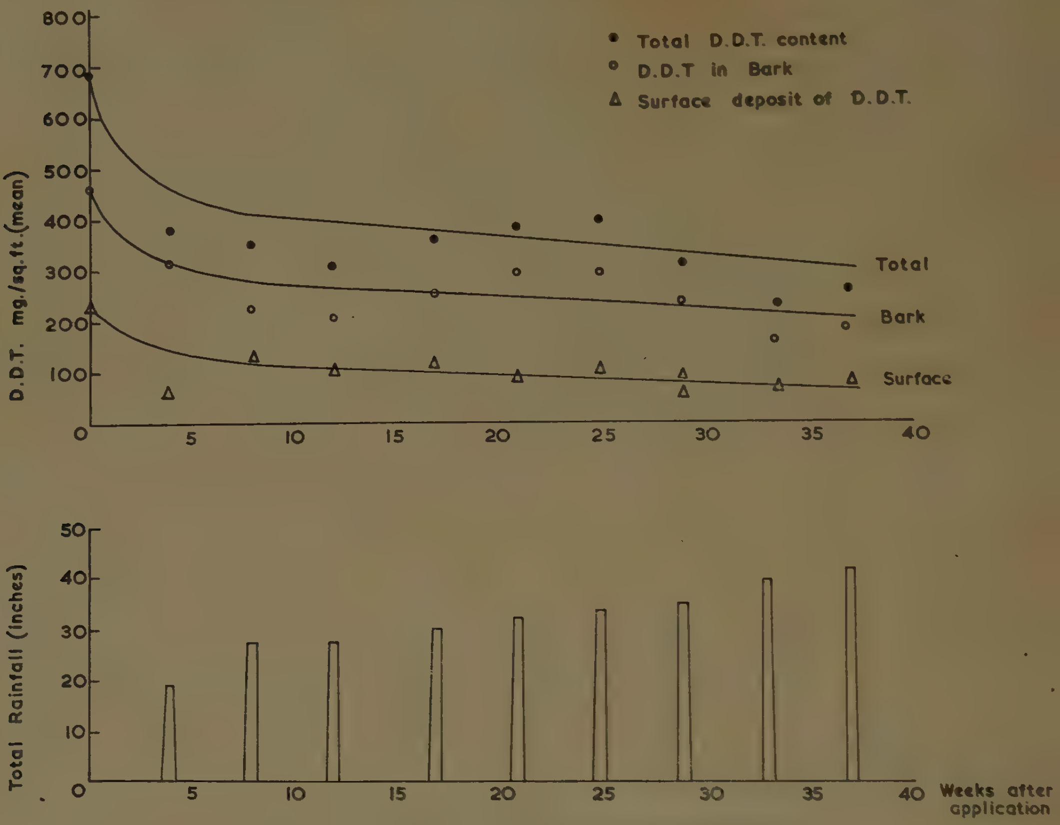

Fig. 2.—D.D.T. emulsion + 15–9/L.P. Resin (Experiment 2)

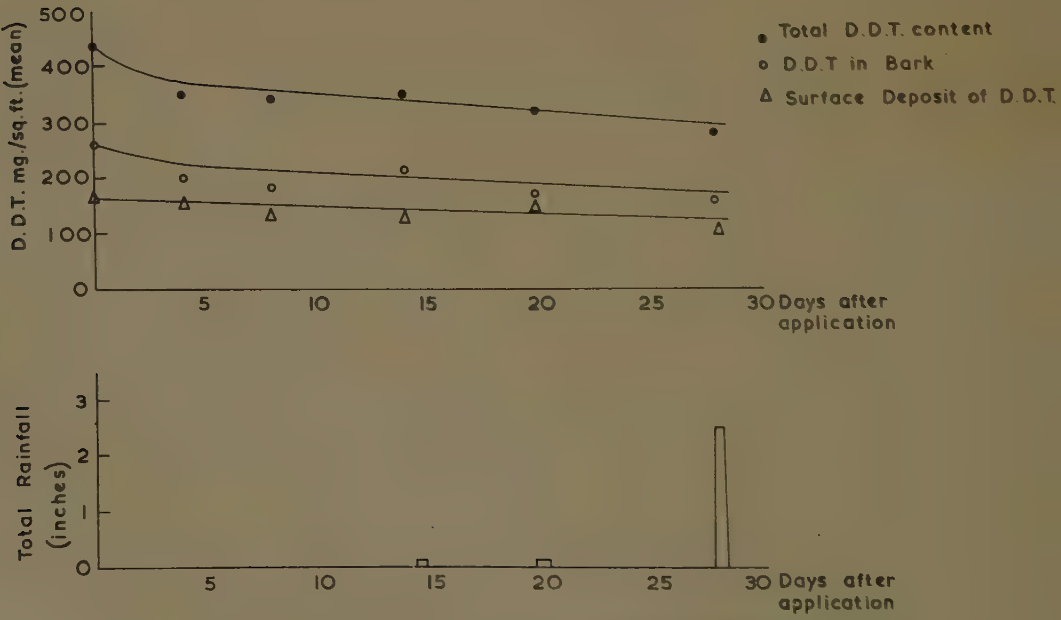

Fig. 3.—D.D.T. content of sprayed section (Experiment 3)

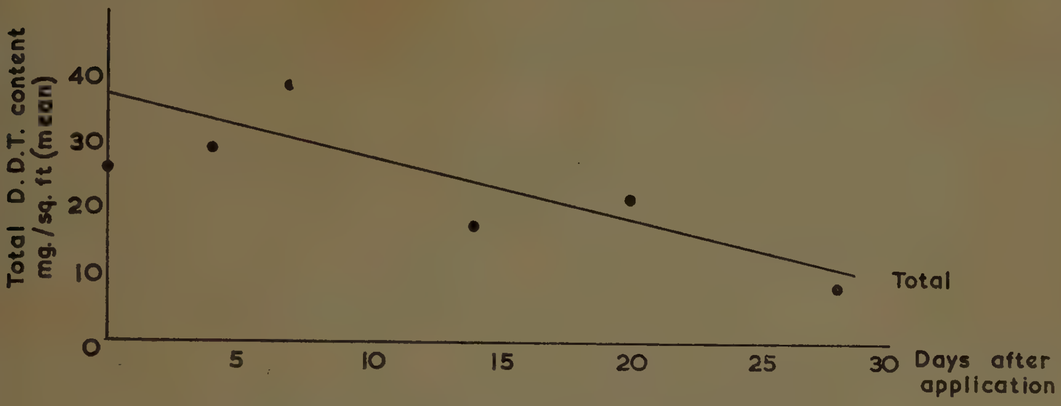

Fig. 4.—D.D.T. content—upper adjacent section (Experiment 3)

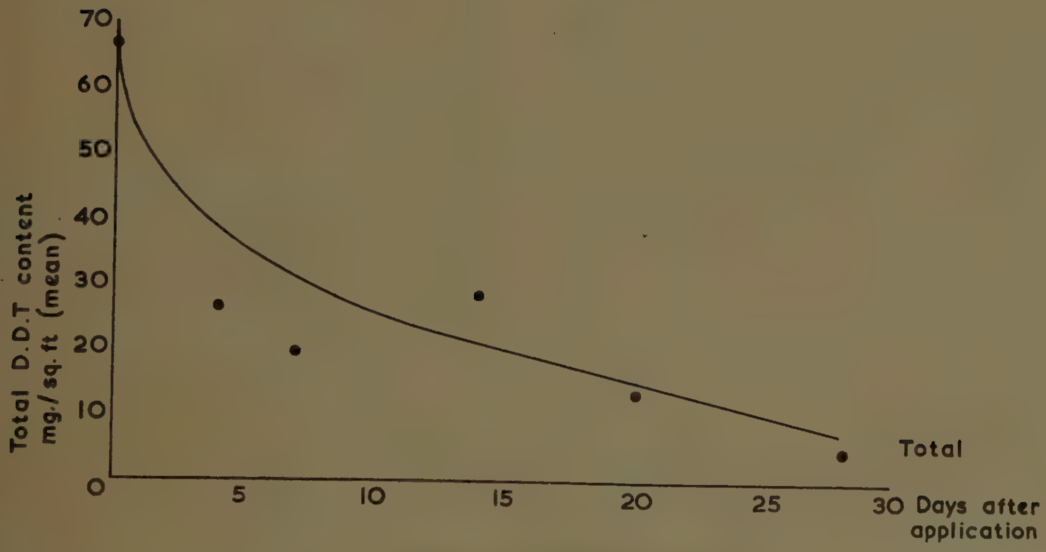

Fig. 5.—D.D.T. content—lower adjacent section (Experiment 3)

DISCUSSION

In all the experiments the total DDT content decreases rapidly during the early stages of the experiment, but the rate of loss decreases with time. The DDT contents of the bast and wood in experiments 1, 2 and 3 (treated section) are small and very similar, and only the results for experiment 1 have been given. It is very probable that these DDT contents are only apparent and not real; it is difficult to obtain a complete separation of the bark, bast and wood, and the figures obtained for the bast and wood are probably the result of experimental error arising from contamination of these samples by small amounts of bark. This conclusion is supported by observation of the penetration by dyed emulsions (using oil soluble dyes) into the bark. Only the outer layers of the bark are coloured and no dye is absorbed through to the bast at liquid dosages equivalent to those used in the DDT applications. Owing to the fissured natured of the bark some of the emulsion penetrates directly behind the outer surface—a point which may be of biological importance as such direct penetration may give zones of fairly high DDT content near the habitat of boring larvae.

The exact significance of the DDT content of the surface washings is difficult to decide, but there appears to be little difference between the rates of loss of DDT from the surface deposit and in the bark.

The rapid initial loss of the insecticide in experiments 1 and 2 followed by a very slow decrease in DDT content, may be due either to a discontinuity in the behaviour of the DDT deposit, or to the regression being of a non-linear type or the heavy rainfall at the beginning of the experiments. Experiment 3 was made to test the possibility of a discontinuity in the initial behaviour of the insecticide arising from translocation of the DDT before the emulsion had been destroyed by volatilization of the solvent. The results do not, however, support the theory of translocation in the initial stages; there is no evidence of any significant movement of DDT into the adjacent unsprayed sections of the bark. One could, of course, postulate that translocation of the DDT would result in it accumulating in either the roots or leaves of the trees, but no experimental confirmation of this could be obtained. Similarly, it is doubtful if rainfall is responsible for the initial high rate of loss since there is a similar loss in experiment 3 although the rainfall was small.

That the regression is continuous and not discontinuous was supported by a statistical analysis of the data. The experimental results consist of the DDT content of the barks of randomly selected trees; the relationship between the mean DDT contents (total) at various time intervals and the time since treatment is of an exponential, or polynomial, type and, as such, is difficult to handle. However, the relationship between the logarithm of the total DDT content and the logarithm of the time since treatment appeared to be approximately linear. The regression lines, using the transformed variates were therefore calculated, and the linearity of the regression checked by an analysis of covariance (Tippet, 1952). Experiment 1 (emulsion only) gave the following regression equation:—

$$\log_{10} (\text{DDT content}) = 2.7694 - 0.1924 \log_{10} (T + 1)$$

where T is the time in weeks since the trees were sprayed. The variance ratio, mean square of deviations from regression compared with the within sample groups mean square, showed that the transformed data did not deviate significantly from linearity. In experiment 2 (emulsion + resin), however, the variance ratio indicated significant deviations from linearity. Experiment 3 (emulsion only) again gave a linear regression:—

$$\log_{10} (\text{DDT content}) = 2.3690 - 0.116 \log_{10} (t + 1)$$

where t is the time in days since spraying.

It would appear, therefore, that the persistence of the DDT is affected, in experiment 2, by the presence of the resin.

The nature of the causal relationship, if any, which gives rise to this linear regression of the transformed variates in experiments 1 and 3 is not clear, but the most probable cause of the loss of the insecticide is the volatilization of the DDT. The biological efficiency of the DDT deposits has been investigated independently (R. G. Tapley, private communication), but assuming that the DDT is biologically available, it would appear that the trees can be protected against attack by the coffee borer for several months.

ACKNOWLEDGMENTS

The work was financed from C.D. & W. funds at the disposal of the Colonial Pesticides Research Committee, and is published with the permission of the Officer-in-Charge, Colonial Pesticides Research Unit, Arusha. We are also grateful to Mr. R. G. Tapley, Entomologist, Coffee Research Station, Lyamungu, for assistance with the field trials.

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TRIALS WITH VIRUS RESISTANT CASSAVAS IN TANGA PROVINCE, TANGANYIKA

By A. H. B. Childs, Department of Agriculture, Tanganyika

(*Received for publication on* 16*th May*, 1957)

Material of 37 cassava hybrids was received from the East African Agriculture and Forestry Research Organization, Amani, for multiplication and further testing in 1952 and 1953. By the long rains of 1955, eight varieties had been selected on the basis of resistance to virus disease and yielding qualities, and further tests were carried out at 32 centres in Tanga and Pangani Districts. The varieties chosen were all third back-cross hybrids from a cross between cassava and ceara rubber (*M. glaziovii*) namely:—

1. 46106/26
2. 46106/27
3. 46110/8
4. 4697/4
5. 4763/16
6. 4763/4
7. 4759/23
8. 4760/37

The object of the trials was to demonstrate to the local cultivators the higher yielding qualities of virus-resistant varieties and the superiority of ridge planting over planting on the flat. It was hoped to select a suitable variety for mass distribution in the districts. The hybrids were therefore compared with the local varieties *Fungamkia,* which shows some resistance to mosaic, and *Gide,* which is highly susceptible but popular with the cultivators since its bitterness deters pigs. At the 32 centres the plots, which were approximately a quarter of an acre, were sub-divided to compare the following treatments:—

1. A selected E.A.A.F.R.O. variety planted on ridges.
2. The same variety planted on the flat.
3. A local variety showing some resistance to virus diseases planted on ridges.
4. The same variety on the flat.
5. A local variety known to be highly susceptible to virus diseases and planted on ridges.
6. The same variety on the flat.

The conditions varied from the red laterite soils of Muheza with an average rainfall of 45 inches, to the sandy soils a few miles from the coast with a rainfall of 30 inches, and the coastal sands with a rainfall of 52 inches. The growing conditions were poor during the 12 months of growth (April, 1955, to March, 1956), the roots being underdeveloped at the time of harvest. However, the plants were cropped in order to obtain yield figures after 12 months' growth, and to provide material for further trials and distribution in the districts.

Establishing Cuttings

In previous years it was found that some varieties established much more easily than others, and that on the coastal sands better establishment was always obtained with ridge planting than with planting on the flat. This did not apply to the same extent on the red soils. Observations were made with the results shown in Table I.

TABLE I—PERCENTAGE OF ESTABLISHMENT

VARIETY	RED SOILS			SANDY SOILS		
	No. of plots	Ridge	Flat	No. of plots	Ridge	Flat
		per cent	*per cent*		*per cent*	*per cent*
46106/26	1	38	33	1	38	Not planted
46106/27	5	85	77	7	86	51
46110/8	1	50	Not planted	1	58	42
4697/4	1	80	Not planted	1	77	Not planted
4763/4	1	20	5		Not planted	
4763/16	4	60	28	1	62	Not planted
4759/23	1	80	73		Not planted	
4760/37	1	70	Not planted		Not planted	
Fungamkia	8	49	43	3	41	32
Gide	6	59	41	4	37	17

Production of Planting Material

One of the main objects of the trials was to find a suitable variety which could be quickly multiplied. It had been observed in previous years that some varieties, although they were fair yielders and showed resistance to virus, made very poor wood growth and therefore gave very little material for cuttings. It was decided to discard these, as the process of distributing them would take a long time. In this respect the two best varieties were 46106/27 and 4763/16; the varieties 46106/26 and 4697/4 were variable, and varieties 46110/8 and 4763/4 were very poor. The local varieties were also rather poor.

Degree of Resistance

Table II shows the percentage of diseased plants observed in the various varieties during the growing period.

TABLE II—PERCENTAGE OF DISEASED PLANTS

Variety	Red Soils		Sandy Soils	
	Mosaic	Brown Streak	Mosaic	Brown Streak
	per cent	*per cent*	*per cent*	*per cent*
46106/26	98	Not seen	100	Not seen
46106/27	2	Not seen	5	Not seen
46110/8	10	30	3	33
4697/4	7	1	5	1
4763/16	2	Not seen	2	Not seen
4763/4	2	Not seen	2	Not seen
4759/23	Not seen	Not seen	Not planted	
4760/37	20	Not seen	60	Not seen
Fungamkia	100	19	100	16
*Gide**	100	16	100	17

* It is impossible to find any mosaic-free plants of the variety *Gide*; consequently the cuttings used were all carrying this virus.

The percentage of mosaic on 46106/27 on the sandy soils would have been lower but for the fact that some of the plots were eaten down on several occasions by goats; this pruning-back of the shoots seemed to induce the appearance of symptoms. In many cases the symptoms were transient and could not be seen later in the trial. The variety 46106/26, although badly infected with mosaic, yielded well; it will, however, be discarded for general distribution as it would be a constant source of infection, and would confuse cultivators, who are being taught to plant only clean cuttings. Brown streak showed up very badly on 46110/8 and slightly on 4697/4. The disease appeared worse at the foot of the mountains, where the nights at some times of the year can be chilly. The roots of the local varieties, especially *Fungamkia*, had started to rot at the time of harvest. Local cultivators never leave this type in the ground longer than necessary for this reason.

The variety 4759/23 was free of virus, but was discarded because of the small amount of planting material produced and because of its poor performance elsewhere. The variety 4763/16 was healthy and vigorous; when mosaic symptoms did appear they were nearly always transient and limited to one or a few branches.

Palatability

Palatability is an important feature for the quick multiplication of any variety for general distribution. The varieties 46106/27 and 4763/16 are very popular on this acount; and in all areas, where they have been grown, and given to the inhabitants for testing, they have been in big demand. The people are, therefore, far more likely to look after them for future plantings.

Unfortunately all the varieties that have most of the desirable qualities are sweet, and this is a big disadvantage in areas where pigs are present. On one demonstration plot the entire section of 46106/27 was uprooted by pigs, whereas the local variety *Gide* was untouched.

The variety 4697/4 was at one time considered to be bitter, but the degree of bitterness appears to vary with growing conditions and it is rarely bitter until fully mature. It is usual for cultivators in pig country to plant the perimeter of their plots with a bitter variety to deter pigs from the sweet variety, which is planted in the middle. Unfortunately the bitter variety is *Gide*, which definitely deters the pigs, but is extremely susceptible to mosaic; a mosaic-free plant of this variety has never been seen in the districts.

Trials will continue with further Amani varieties to find a suitable bitter type.

Methods of Cultivation

Ridge and flat planting were compared in the plots and it was found that in nearly every case the ridge gave twice the yield of the flat. The plants were much more vigorous and apart from giving more crop they also supplied more material for multiplication. It was found to be much easier to harvest the roots from a ridge than on the flat. On sandy soil it was only necessary to pull the plant out of the ground, no digging being required.

TABLE III—YIELDS IN POUNDS PER PLANT

Variety	Red Soils		Sandy Soils	
	Ridge	Flat	Ridge	Flat
Hybrid—				
46106/26 ..	8·0	7·2	7·3	—
46106/27 ..	6·3	4·3	5·0	3·3
46110/8 ..	3·4	—	3·4	—
4697/4 ..	3·1	—	8·0	—
4763/16 ..	6·4	3·2	16·6	—
4763/4 ..	Plots abandoned owing to poor establishment.			
4759/23 ..	5·7	1·8	—	—
4760/37 ..	4·8	—	—	—
Fungamkia ..	5·2	3·1	2·3	1·9
Gide	5·0	2·8	2·8	1·2

The superiority of the hybrid clones is greater if yield per acre is considered, since in most cases the percentage establishment of these varieties was much higher. The yields from the hybrids were interesting especially on the sandy soils, where 46106/27 gave double that of the local. On the more fertile soils the differences were smaller; but it is on the sandy soils where the majority of the cassava is grown, that improvement is most required. The crop is necessary for cash as well as food, until perennial cash crops are established.

The figure "lb. per plant" is the mean from the number of plots planted of each variety. In some experiments only one plot had been planted, but they were of sufficient size to give a reasonable result. On sandy soils 46106/27 was the only variety tested against the local, as from previous experience this was considered the most suitable for these conditions.

Selection of Varieties and Further Work

The two varieties chosen for multiplication and distribution were 46106/27 for the sandy soils and 4763/16 for the red soils. The variety 46106/27 was chosen because it showed up well in all the tests. It was easy to establish on both types of soil, produced abundant planting material, showed a high degree of virus resistance, and yielded well. It showed up particularly well on the poorest soils: at Kibafuta, for example, it yielded 3.6 tons per acre compared to 0.3 tons by the local diseased variety.

In the long rains of 1956 the variety was planted at 16 centres on the sandy soils to give a total area of approximately 12 acres, and in addition five acres were planted by 50 Africans on plots containing from 50 to 1,000 plants. In all cases the cuttings established well in spite of poor rains, Tanga District being 20 inches below average at the end of November.

The plots were rogued, and it was found that the percentage of mosaic at the end of November was seven; no symptoms of brown streak were observed. The percentage has risen 2 per cent since the 1955 plantings, but the areas are more varied and larger. Conditions are more difficult in that, owing to lack of rain, the plants have not made normal growth, and some plots planted by Africans are small, and in the midst of heavily infected areas.

In spite of all this the variety is much more vigorous and healthy looking than the local. If the percentage of mosaic remains around the present level, the variety is well worth continuing with. In the long rains of 1957, nine acres of cuttings will be taken, and distributed in one concentration on the sandy soils, so that after two to three years the particular area should be free of local varieties and clearer of mosaic. The whole experiment depends on the damage that may be done by pigs, as if they damage this variety more than the local one it will deter the inhabitants from continuing with its multiplication. On the other hand if the perimeters of the plots are planted with *Gide*, a source of infection for the clean material will persist. A virus-resistant bitter variety is the answer, but is not yet available. Other sweet varieties that are being multiplied for testing are reputed to be much more virus-resistant than 46106/27, and may not be influenced by the presence of diseased *Gide*.

The variety 4763/16 has been chosen only for the red soils since in tests done by E.A.A.F.R.O. it did not establish as well as 46106/27 under difficult conditions, and may not be suitable for the sandy soils. In other respects it has given results at least as promising as those for 46106/27.

STUDIES OF THE BROWSING AND REPRODUCTIVE BEHAVIOUR OF THE EAST AFRICAN DWARF GOAT

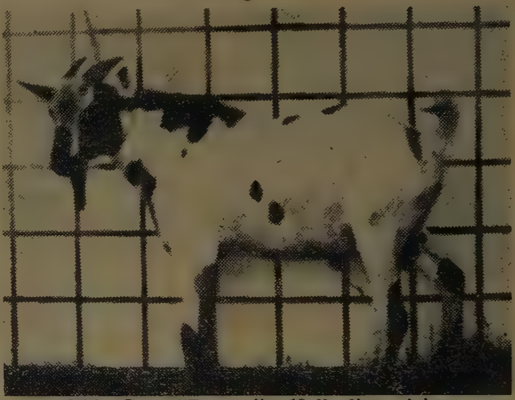
By **P. N. Wilson, University College of East Africa, Kampala, Uganda**

(*Received for publication on 4th June, 1957*)

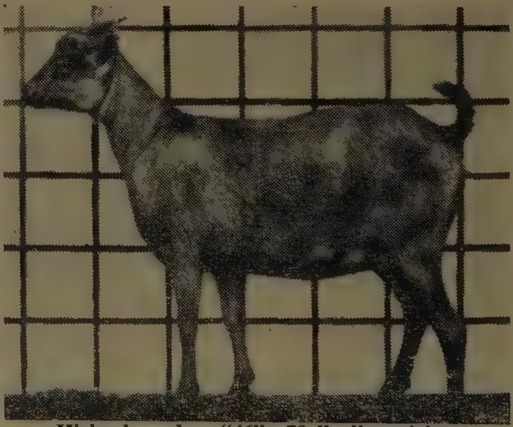
Many articles have been written with the object of condemning the goat as the major cause of deforestation, soil exposure and consequent erosion. Such arguments have been reviewed and supported by Maher (1945). On the other hand there is some evidence, summarized by Hornby *et al* (1948) that the goat is not the major cause of erosion, and may be beneficial because of its browsing habits which inhibit bush encroachment.

The following observations aim at adding to our knowledge of the East African dwarf goat by presenting records of their browsing behaviour at Serere, Uganda, under conditions of comparatively high mean maximum temperature (86.5°F.) and fairly high mean annual rainfall (53.6 inches). The goat studied was the indigenous East African dwarf goat, thought by Epstein (1953) to be a pituitary hypoplasia recessive mutant of *Capra reversa* (Linn.). Typical animals are shown pictorially in Fig. 1.

Fig. 1



Billy Goat "Rumen"—68 lb. liveweight



High plane dam "46"—78 lb. liveweight

Low plane Dam "9"—32 lb. liveweight

Serere is situated in the Teso District of Uganda at 1° 32′ N.; 33° 27′ E., at an altitude of 3,900 ft. The Serere rainfall is bimodal with most rain falling April/May and a second rainy period August/September. Serere is in the so-called "short-grass" area of Uganda, classified as *Hyparrhenia filipendula* grassland community by Snowden (1953). A list of the Serere grass species has been presented by Hosking and Stephens (1941).

The objects of the behaviour trials were:—

(1) To obtain basic information on the normal behaviour of East African dwarf goats kept in the Serere environment.

(2) To find whether different systems of management resulted in any differences in behaviour pattern.

MANAGEMENT AND NUTRITION OF THE EXPERIMENTAL HERD

The different systems of management described in this paper were based upon the requirements of an experiment on goat physiology (Wilson, 1956). Briefly, 55 kids from local Teso goats were produced from 51 nannies and two billies. During pregnancy all goats were kept on a steadily rising plane of nutrition reflected in a mean liveweight gain of between 2 lb. and 3 lb. per head per month. After kidding, the goats were divided at random into two groups. One group was fed on a high plane of nutrition (H) and the other on a low plane (L).

The system of management employed was similar to that adopted in most parts of East Africa. Goats were housed at night and allowed out for a controlled period of browsing each day. This controlled browsing formed the basal diet of both the H and L plane goats, and was fixed at 2½ hours per day, sufficient to provide between one and two hours' "effective browsing time". The L plane goats relied exclusively on the basic browsing period for their nutrition. The H plane goats received two supplements (*a*) An extra daily period at browse varying between two and four hours in duration. This provided between one and a half and two and a half hours' extra "effective browsing time". (*b*) A supplementary ration fed *ad lib* each morning and evening. This ration was designed to have a nutritional ratio of 1:7 (French, 1944), and its composition and analysis are shown in Table I.

TABLE I

Foodstuff	Percentage in Ration	Percentage		Total	
		S.E.	P.E.	S.E.	P.E.
Whole cotton-seed meal	60	62	9	37·2	5·4
Finger millet meal	25	60	8	15·0	2·0
Tepary beans* ..	8	69	15	5·5	1·2
Groundnuts (crushed) ..	6	131	23	7·9	1·4
Mineral Mixture	1	—	—	—	—
Total ..	100	—	—	65·6	10·0

Nutrient Balance 6·6:1

*No accurate analysis of tepary beans available.

CHEMICAL ANALYSIS OF RATION

	per cent
Crude Protein	18·6
Ether extract	11·4
Crude Fibre	21·4
Ash	4·0
N.F.E.	44·6

(*Walker*, 1955)

The growth of the kids was chiefly governed by the nutrition of their dams, since all kids were suckled and did not receive supplements until they reached 12 lb. liveweight. The nutrition of the two groups of kids is summarized in Table II, and the effect of nutrition on the liveweight gains of the kids is shown graphically in Fig. 2.

TABLE II—THE DIFFERENT NUTRITION OF KIDS WITH INCREASING WEIGHT

Stage of Growth	High Plane Kids	Low Plane Kids
Birth—12 lb. ..	Milk+Concentrates	Milk.
12 lb.—15 lb. ..	Milk+Concentrates +free range.	Milk.
15 lb.—22 lb. ..	Milk+Concentrates +free range.	Milk+tethering.
22 lb.—25 lb. ..	Milk+Concentrates +5 hours browse.	Milk+2½ hrs. browse.
25 lb.—33 lb. ..	Milk+Concentrates +5 hours browse.	2½ hrs. browse

The goats under observation in the behaviour trials were as follows:—

Group 1.—Four pregnant dams enjoying the rising plane of nutrition. (Object 1).

Group 2.—One billy-goat, managed in the same manner as Group 1. (Object 1).

Group 3.—Five H plane lactating dams and five L plane lactating dams. (Object 2).

Group 4.—Four H plane kids and four L plane kids selected from the herd in such a way that both groups were balanced for mean age and sex. (Object 2).

The behaviour of the goats was observed during each trial for a continuous period of 24 hours from 06.00 hours. During each trial the following activities were recorded: 1, browsing (B); 2, eating bedding (B); 3, walking, but not browsing (W); 4, standing and ruminating (SR); 5, lying and ruminating (LR); 6, drinking water (D); 7, standing idle (S); 8, lying idle (L). In the case of Group 4 (kids) suckling milk (DM) was also recorded. In the case of the billy-goat sexual activity (C) was also recorded (i.e. calling to the female prior to coitus and coitus). Behaviours 7 and 8 were grouped together as "Time spent idle" and all the remaining activities were considered as "Time spent working".

The number of goats in each group was small because of the difficulty in accurately recording more than ten goats at a time. The interval between recordings was five minutes. The optimum interval is generally calculated to be four minutes (Hughes and Reid, 1951, and Harker *et al.*, 1954), but this interval had to be increased due to the great activity and small size of the dwarf goats used in these studies.

EXPERIMENTAL RESULTS

Differences Between Observers

In order to obtain an estimate of the maximum errors which could be introduced into the trials due to the personal differences in recording, the team of eight observers was tested simultaneously against each other. An analysis showed that no observer had a statistically significant difference in his records from any other, but that there was a tendency for some observers to score more heavily under "walking" and less under "browsing" and vice versa.

Differences Between Individual Animals Within a Group

During two trials the group of five (H) dams were recorded individually for each goat in order to estimate the variation between animals within a group. The results showed that the variation between different animals within a group was small, and that it could be ascribed mostly to differences in the times different goats spent ruminating. There was a difference in lying ruminating (LR) and standing ruminating (SR) times added together, which was significant at the five per cent level. Also, there was a difference between individual goats on time spent idle which was not statistically significant but probability was low at P = 20 per cent. It was concluded that the differences between goats within a group were small, and should not mask large differences in activity between groups on different treatments.

Differences Between Trials of the Same Group of Goats

Having shown that the variation between animals in one group on any given day was small, the next step was to find the week-to-week variation in habit due to environmental factors. The data employed for this purpose were those of the billy-goat since this goat was not changing much in weight, and was not subject to the various physiological changes occurring in all other groups. The summarized results of the four observation trials of the billy-goat are presented in Table III.

Table III shows that the variation in behaviour from one trial to another was pronounced, but that it was accounted for by differences within the sub-divisions of the major activities rather than in the major activities themselves. The only activity to remain constant in duration throughout all trials was walking time. Browsing time had a relatively low standard deviation. The number of hours spent out at browse (as distinct from the hours actually browsing) was 4.5, 4.5, 4.5 and 4.7 respectively for the four trials.

The ruminating times were fairly constant apart from the last trial. The total hours spent ruminating were 7.1; 7.0; 7.3 and 9.6 respectively. The mean browsing: ruminating ratio, with browsing time taken as unity, was 1:3.7.

The ratio of idle time to working time was fairly constant at approximately 1:1. The increased ruminating time in the last trial increased the working time by almost two hours, so that in this trial working time exceeded idle time. Fifity-nine per cent of the idling time occurred at night. In every trial more time was spent lying idle than standing idle.

No time has been recorded for drinking. The goats regularly drank water for between one and three minutes immediately on return from browsing, but this short period was usually missed by the technique of sampling behaviour every five minutes. The times of drinking water were, however, recorded separately and the results showed that no drinking took place at any time during the day or night apart from the period immediately after return from browsing, although fresh water was always available.

TABLE III—BEHAVIOUR PATTERN OF THE BILLY—HOURS SPENT AT EACH ACTIVITY

TRIAL NO.	L	LR	S	SR	W	B	C	B:R ratio	Hours idle	Hours work
2 Total	7·9	4·6	4·4	2·5	2·0	2·0	0·6	1:3·6	12·3	11·7
3 Total	6·9	3·6	5·8	3·4	2·0	2·0	0·3	1:3·5	12·7	11·3
7 Total	6·9	3·3	5·3	4·0	2·0	2·5	—	1:2·9	12·2	11·8
10 Total	4·9	6·9	5·2	2·7	2·0	2·1	0·2	1:4·6	10·1	13·9
Mean of 4 Trials	6·7	4·6	5·2	3·1	2·0	2·1	0·3	1:3·7	11·8	12·2
Maximum hours in any activity	7·9	6·9	5·8	4·0	2·0	2·5	0·6			
Minimum hours in any activity	4·9	3·3	4·4	2·7	2·0	2·0	0·2			

The sexual activity recorded mostly took place in the early morning. The billy was housed in a separate pen and on releasing the goats at 06.30 hours the billy immediately commenced sexual display whenever a female was showing signs of oestrus. On certain occasions the billy was observed to serve a female already in the early stages of pregnancy. The relevant records are presented in a later section, "Reproductive Behaviour".

Comparison of Behaviour Between the Sexes

The next subject of study was the comparison of the behaviour pattern of the four pregnant females (Group 1) with that of the billy. Numbers of animals in each group are too small for statistical analyses to be used, but the trials were replicated in time and certain differences in behaviour were apparent. The relevant data are presented in Table IV.

The data indicate that there are differences in behaviour between the two sexes. Contrary to expectation, the male spent appreciably longer ruminating than the four pregnant females. Total ruminating time for the mean of the female groups was only 5.9, compared to 7.7 hours for the male. This has resulted in the browsing: ruminating ratio of the female group of 1:2.8 compared to 1:3.7 for the male. Browsing and walking times were almost identical for both sexes, in each case these activities took up nearly half the period the goats spent in the browsing area. As a result of the longer period spent ruminating, the male "worked" for about two hours longer each day than the females. A further difference was that the male spent more time lying and less time standing than the females.

It is emphasized that due to the inability to replicate the goats in the Group 2 the above differences may be due to exceptional individual behaviour of the single billy-goat under observation. It is, however, interesting to note that the female group, in advanced stages of pregnancy, spent the same time in prehension, and *less time* in mastication, of food than the male goat, and that a mere two hours' effective browsing each day, supplemented by about half a pound of concentrates, was quite sufficient not only for maintenance but also to provide sufficient nutrients for the growth of the foeti and for liveweight gains of approxmately one pound per head per week. These results suggest that further work should be carried out to see whether female goats are more selective in their feeding habits than males.

Differences in Behaviour Between H Plane and L Plane Dams

After parturition, the dams were placed on two contrasted systems of management. Two trials were conducted to find the effect of these systems of management on the behaviour of the dams. Data showed that the L dams were slowly losing body-weight, whilst the H dams gained in liveweight during their lactation period. Table V presents the results of these trials, together with the mean figures for the two trials on pregnant dams described above.

TABLE IV—COMPARISON OF BEHAVIOUR BETWEEN SEXES

TRIALS	L	LR	S	SR	W	B	B:R ratio	Hours idle	Hours work
Females—Mean of 2 trials	7·0	2·7	6·8	3·3	2·1	2·1	1:2·8	13·8	10·2
Male—Mean of 4 trials	6·7	4·6	5·2	3·1	2·0	2·1	1:3·7	11·8	12·2
					plus 0·3 hours sexual activity				

TABLE V—THE BEHAVIOUR PATTERN OF FIVE H PLANE DAMS AND FIVE L PLANE DAMS

TRIAL NO. PLANE	L	LR	S	SR	W	B	D	B:R ratio	Hours idle	Hours work
5 H Total	5·9	5·1	4·7	3·7	1·1	3·4	0·1	1:2·6	10·6	13·4
L Total	5·1	6·6	6·5	2·8	1·8	1·2	—	1:7·8	11·6	12·4
8 H Total	5·4	3·3	6·8	4·2	1·7	2·6	—	1:2·9	12·2	11·8
L Total	6·1	3·8	6·7	4·3	1·5	1·6	—	1:5·1	12·8	11·2
Mean H dams Total	5·6	4·2	5·8	4·0	1·4	3·0	—	1:2·7	11·4	12·6
Mean L dams Total	5·6	5·2	6·6	3·6	1·6	1·4	—	1:6·3	12·2	11·8

The major differences in behaviour were the result of the different number of hours allowed out at browse. This is reflected in the effective browsing time, which averaged three hours for the H plane and 1.4 hours for the L plane goats. Ruminating times, however, were relatively constant at 8.2 hours and 8.8 hours respectively; the L dams ruminated for somewhat longer than the H in spite of less time browsing. This has resulted in markedly differing browsing: ruminating ratios, 1:2.7 and 1:6.3. The H plane dams had not increased their ruminating time to deal with the greater bulk-intake, nor had the L plane dams increased their rate of feeding during their shorter browsing period by more efficient browsing. Test weighings, before and after browsing, showed that the H dams gained approximately 4 lb. weight and the L dams approximately 3 lb. weight during the browsing period, no allowance being made for loss in weight through natural causes. Possibly the L plane goats were less selective in their feeding habits because of their greater appetite, resulting in an intake of coarser food material, requiring a longer period of rumination for its breakdown.

The L dams occupied their time between 11.00 and 14.00 hours standing idle while awaiting their chance to go out to browse. The idling time of this group was, therefore, higher than that of the H, and both groups spent more time in the standing position than in the lying position. Both H and L groups of lactating dams spent more hours working than the pregnant dams.

H and L dams both spent part of the night eating or nibbling at their bedding whilst standing during the night to suckle their kids. Very little bulk was consumed during this night activity, but it has been included with browsing time in calculating the browsing: ruminating ratios.

Both groups of lactating dams were more efficient than the pregnant group in their efficiency during the browsing period. The lactating females spent only one hour walking to every 1.4 hours browsing, whereas the pregnant group (like the male goat) divided time at browse equally between walking and browsing. The type and quality of browse available to the goats was fairly constant for all trials and this difference in browsing intensity was sufficient to be noticeable to the observers in the field.

Differences in Behaviour of the H Plane and L Plane Kids

The final comparison was of the behaviour of the H and L kids at various stages of growth. The trials were six in number, and covered the ages from 23 days to 113 days. The means of the data for these six trials are presented in Table VI. Histograms expressing the results of trial number 13 are presented in Fig. 3.

The total feeding times of the H and L kids are very similar, but whereas the rapidly-growing H plane kids quickly changed from a milk to milk-plus browse diet, the slower-growing L plane kids relied more on the milk of their dams than on browsing material. The L plane kids suckled much more frequently than the H, the difference being much greater than that shown by the data obtained from sampling behaviour only every five minutes. During two trials records were kept of the number of times the kids suckled at night. The L plane kids averaged three/four suckling periods per hour, the H plane kids only just over two periods per hour. Whereas the H kids suckled for periods lasting on average just under two minutes, the L plane suckling periods were only about one minute.

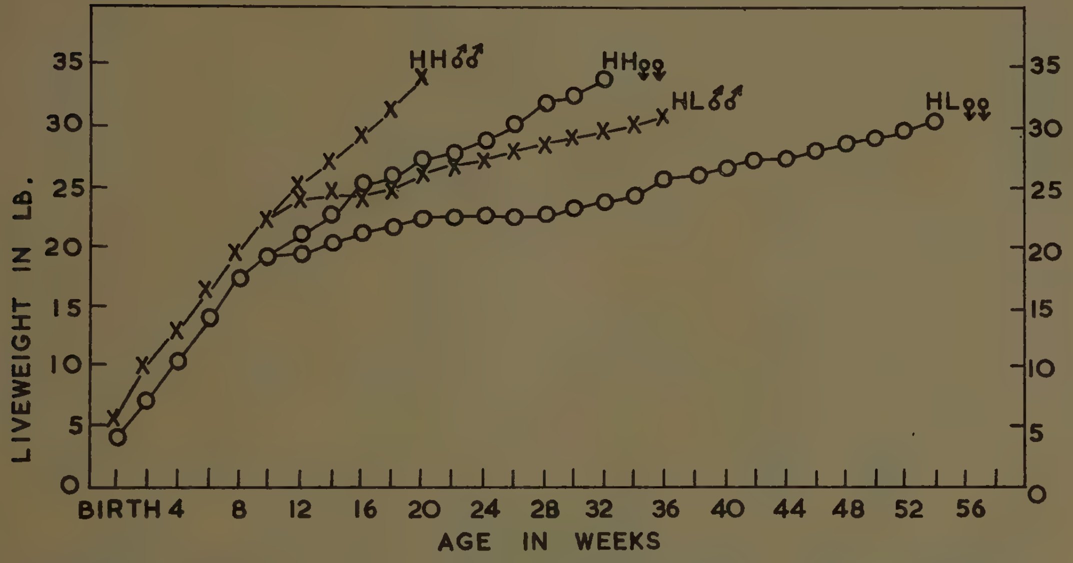
It was of interest to find that ruminating commenced before the kids had any access to browsing, when the only bulky foods consumed could have been a few wisps of bedding hay plus, in the case of the H plane kids, small quantities of concentrates. The kids started browsing when they were between

TABLE VI—BEHAVIOUR PATTERN OF FOUR H PLANE KIDS AND FOUR L PLANE KIDS—MEAN OF SIX TRIALS

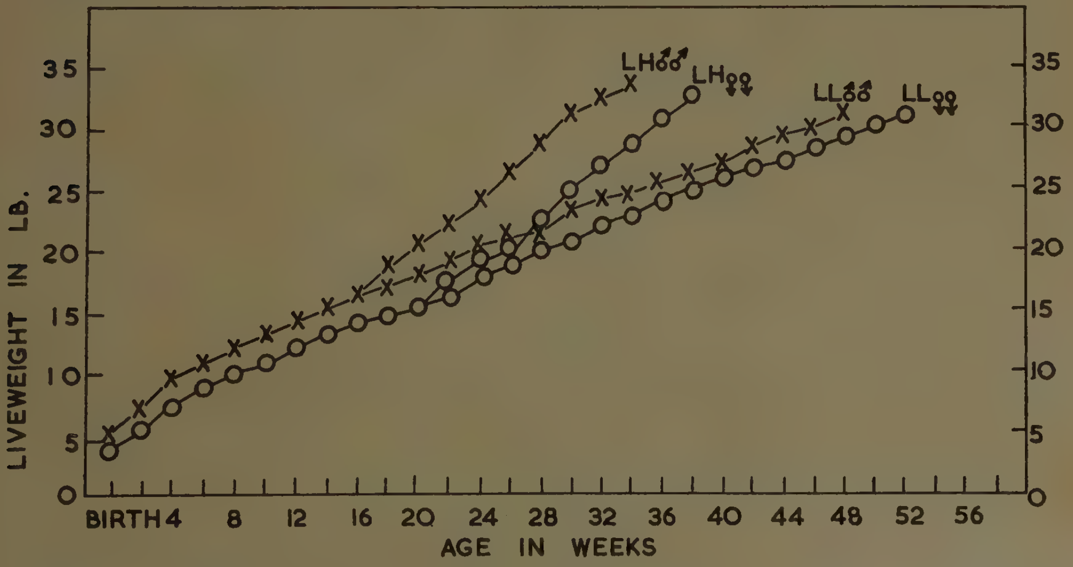
PLANE	L	LR	S	SR	W	DM (milk)	B	B:R ratio	Hours idle	Hours work
H kids Total	8·7	2·8	5·8	1·3	2·0	1·0	2·4	1:1·7	14·5	9·5
L kids Total	8·4	2·9	5·5	1·8	1·9	1·3	2·2	1:2·1	13·9	10·1

Fig. 2

GROWTH CURVES OF KIDS SHOWING SEX DIFFERENCES



GROWTH CURVES OF INITIAL HIGH PLANE GOATS TO 33LB LIVEWEIGHT



GROWTH CURVES OF INITIAL LOW PLANE GOATS TO 33LB LIVEWEIGHT

X——X MALES
O——O FEMALES

three and four weeks of age. Table VII presents the browsing and ruminating time for all the kid trials listed in ascending order of mean age.

TABLE VII—BROWSING AND RUMINATING TIMES OF KIDS PRESENTED IN ORDER OF INCREASING AGE

Trial No.	Plane	Mean Age days	Mean weight lb.	Hours spent browsing	Hours spent ruminating
6	L	22·5	9·0	Nil	3·0
6	H	22·8	13·0	Nil	2·6
9	L	29·5	9·5	2·0	1·3
9	H	29·8	14·3	2·2	2·2
11	L	77·5	11·0	3·9	4·7
11	H	77·8	20·5	3·4	4·4
12	L	98·5	13·5	2·8	5·3
12	H	98·8	24·4	3·1	3·6
13	L	105·5	14·0	3·0	5·9
13	H	105·8	26·0	3·0	7·1
14	L	112·5	14·8	3·0	5·9
14	H	112·8	27·5	2·4	4·8

The data suggest that kids commence to browse when a minimum age is reached rather than when they obtain a minimum weight. The variation between trials in browsing and ruminating behaviour of young kids was very great, and was probably due more to changes in environment than to an increase in either age or body weight.

It was noted that the L plane kids responded to cold weather more than the H plane kids. The L kids became less lively on cold days, and when standing they arched their backs in an attitude resembling that of a frightened cat. H plane kids were comparatively unaffected by cold.

The proportion of hours working to hours idle naturally increased steadily with increasing age, from 1:3 at three weeks to the normal adult ratio of approximately 1:1 at 11 weeks of age. The young kid spent three-quarters of the night in the lying position, but most of the idle time during the day was spent standing, generally by the side of the dam when the dam was present.

OBSERVATIONS ON THE GRASSES, HERBS AND TREES EATEN BY GOATS

There are very few references in the literature to actual lists of plants which are most readily eaten by goats. Edwards (1948) has published some notes on the foods of goats in a semi-arid area, and Staples *et al.* (1942) have noted the main species of plants selected by goats in semi-arid "bush" conditions of Central Tanganyika. Both these workers claim that grasses are very seldom eaten by goats when other species are available.

In the course of the present work the goats were observed during their browsing periods for an average of two–three days every week. Every quarter of an hour the main plant species grazed or browsed by the majority of the herd were noted. In all, 379 such sample observations were recorded and the results of these observations are recorded in Table VIII. These results show that 59.1 per cent of the species eaten were trees or bushes, 33.5 per cent of the plants were tall erect or semi-erect grasses and 7.4 per cent were erect or semi-erect herbs. On no occasion were goats observed to be grazing low on the ground. The goats usually preferred to browse herbage which was slightly above their nomal head-height, and the goats were frequently seen standing on their hind-legs endeavouring to reach vegetation 3–4 ft. from the ground.

It is difficult to determine from the data in Table VIII whether these plant species are eaten in the order given because they are present in the vegetation of the browsing area in this order, or whether the goat has chosen these species from amongst others through selective browsing. The area of bushland where the goats browsed was not uniform, and botanical analyses of the vegetation were not carried out. Certain conclusions, however, can tentatively be drawn from these results, together with the qualitative information obtained during the browsing periods by the observers.

The goat does not appear to be very selective as regards plant species, but it is very selective as regards (1) stage of growth of plant material and (2) height above ground of plant material. A list of all the species eaten by the goat at one time or another would embrace nearly all the species present in the area. Very few species are constantly rejected, the most noticeable being *Cassia siamea,* an introduced tree. Most species will be eaten when they display young shoots or young leaves about two to four feet above ground level. The thorny acacias generally meet this requirement, and these bushes, in spite of their thorns, contribute the main proportion of the goats' browsing diet. *Combretum* and *Ficus* trees are well liked by the goats, but they generally stand too high to be within easy reach.

Fig. 3

Behaviour pattern of 4 young low-plane kids and 4 young high-plane kids
0600 hours 18.8.55—0600 hours 19.8.55

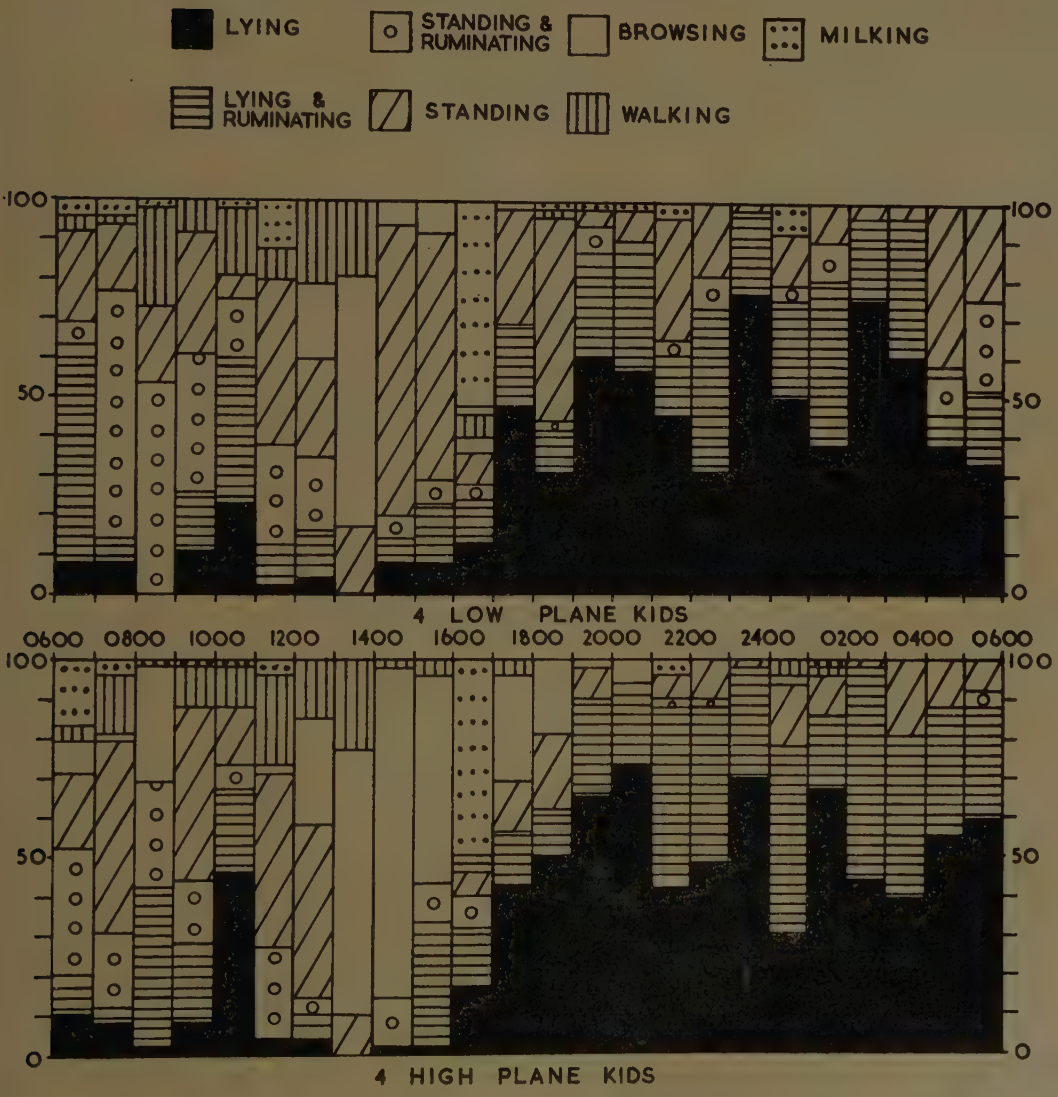


TABLE VIII—PLANTS EATEN BY GOATS

Counts Obtained by Observing the Main Species Being Eaten at Quarter-Hour Intervals by a Herd of Approximately 50 Goats

	Specific Name	Count
Trees and Bushes	*Acacia seyal*	49
	Harrisonia abyssinica ..	31
	Lantana camara ..	30
	Combretum binderanum	21
	Combretum ghasalense	20
	Piliostigma thonningi ..	17
	Albizia zygia	13
	Terminalia torulosa ..	12
	Ficus thonningii ..	7
	Melia azedarach ..	6
	Acacia sieberiana ..	4
	Flueggea virosa ..	4
	Grewia mollis ..	4
	Mangifera indica ..	3
	Ziziphus abyssinica ..	3
		224
	59·1 per cent of all plants eaten.	
Grasses	*Panicum maximum* ..	31
	Chloris gayana ..	19
	Cynodon sp.	17
	Hyparrhenia dissoluta ..	17
	Sporobolus pyramidalis	17
	Eragrostis superba ..	11
	Imperata cylindrica ..	10
	Hyparrhenia filipendula	5
		127
	33·5 per cent of all plants eaten.	
Herbs	*Cassia mimusoides* ..	10
	Pseudarthria hookeri ..	6
	Erigeron grantii ..	5
	Sida sp.	4
	Aframomum sp. ..	3
		28
	7·4 per cent of all plants eaten.	

The high count of *Lantana camara* was of considerable interest. This bush is used as an ornamental hedge plant in many parts of Uganda. At Serere it has spread rapidly and become a most pernicious weed. The goats were observed to have a marked preference for the fruits and flowers of *Lantana*, but the leaves were rarely eaten. After passage through the alimentary canal of the goat *Lantana* seeds were non-viable. *Lantana* was not common on peasant holdings adjacent to Serere on which the goat population averaged 1½ goats per acre. These observations suggest that the goat can prevent the encroachment of *Lantana* thicket, and that the virtual absence of goats from Serere for 25 years is probably an important factor causing *Lantana* to become a troublesome weed of Serere but not of the surrounding district.

Observations have shown that grasses were eaten by goats, contrary to other reports, but that they were eaten in a small proportion compared to trees and bushes. The chief parts of the grass eaten were the inflorescence and the growing shoots. Growing points near to the ground were never eaten, and the light grazing of grasses practised by the herd did not prevent the spread of grasses provided trees were present as an alternative and preferable food source. L plane goats tethered to small restricted areas where there were no succulent shoots on trees or bushes ate down the grass to about 1½ in. from ground level, but this grazing behaviour is not at all typical of goats on free range.

Herbs were rarely eaten by goats. The count of 7.4 per cent was mainly made up of plants which were nibbled in passing as the goats were driven to and from the browsing area. Goats generally ate the tips of the inflorescence, rarely the leaves or stems.

REPRODUCTIVE BEHAVIOUR

The marking of the billies with an oily dye allowed service dates to be accurately recorded. The results obtained enabled the mean gestation period to be calculated. The mean gestation period was 146½ days, with a minimum of 140 days and a maximum of 151 days.

On certain occasions it was found that pregnant females were willing to accept service, and Table IX gives details of the seven goats who were served whilst pregnant. The days shown in the table refer to the number of days pregnant, calculated from the service date which subsequently was found to correspond closest to the mean gestation period of 146½ days.

TABLE IX—SERVICE RECORDS OF PREGNANT GOATS

Goat identification number	Number of days pregnant at time of accepting service
1	52 and 79
2	21 and 27
15	18 and 53
33	15, 22, 30 and 32
34	15
39	5 (?) and 80
54	39 and 52

These records do not reveal any obvious rhythm or cycle in sexual activity during pregnancy. The details of the oestrus cycle of the dwarf goat are not known with certainty.

The mean number of services per live kid born was 2.3. Three of the females purchased proved to be sterile, and 29 abortions were recorded, three of these abortions referring to goats which were served whilst pregnant.

SUMMARY

1. Behaviour studies were carried out for 24-hour periods on four groups of experimental goats. There were no major differences between the behaviour of the several animals within a group at any given trial, but there were small statistically significant differences in the times individual goats spent ruminating.

2. The variability in behaviour of the same animal from one trial to the next was pronounced, but was accounted for mainly by differences within the sub-divisions of the major activities rather than in the major activities themselves. Trial to trial variation was greatest for the behaviour of the goats during the hours of darkness.

3. The results indicate that certain differences in behaviour exist between the sexes. The male spent longer ruminating than the females, resulting in a narrower browsing: ruminating ratio for female goats of 1:2.8 compared to 1:3.7.

4. The major differences in the behaviour pattern of H and L plane lactating dams were due to the different systems of management employed. The longer period at browse of the H plane group resulted in a narrower browsing: ruminating ratio of 1:2.7. compared to 1:6.3 for the L plane group. Ruminating times remained relatively constant for all groups.

5. The differences in behaviour between H and L plane kids of similar ages were very small. As with their dams L plane kids had wider browsing: ruminating ratios, 1:2.1 compared to 1:1.7. The total feeding times of H and L kids were very similar, but L plane kids suckled their dams more frequently during the night than H kids.

6. Observations on the plants eaten by goats showed that over half the browsing time was occupied eating leaves and shoots of trees and bushes, mostly thorny *Acacias*. Grasses were eaten but generally only the inflorescence was eaten and there was no evidence of goats preventing grass establishment and spread. The preference of the goats was for succulent shoots at about head-height. Only very few species were consistently rejected.

7. Observations on the reproductive behaviour of the goats showed that the mean gestation period was 146½ days. Pregnant goats were occasionally willing to accept service, 14 such instances being proven. The mean number of services per kid born was 2.3.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to the Director of Agriculture for permission to conduct this work at the Departmental Experiment Station at Serere; to the Makerere College Research Grants Committee for financing the project, and to the University of London for permission to publish the work.

Thanks are also due to Mr. D. J. Parsons, for assistance in finding accommodation for the herd at Serere, to Messrs. D. Echonyu and A. Okech, livestock assistants, to Mr. W. R. Ingram for help with photography, and to Professor Fergus Wilson, Mrs. M. E. Wilson and Mrs. G. Poole for assistance in the preparation of the manuscript.

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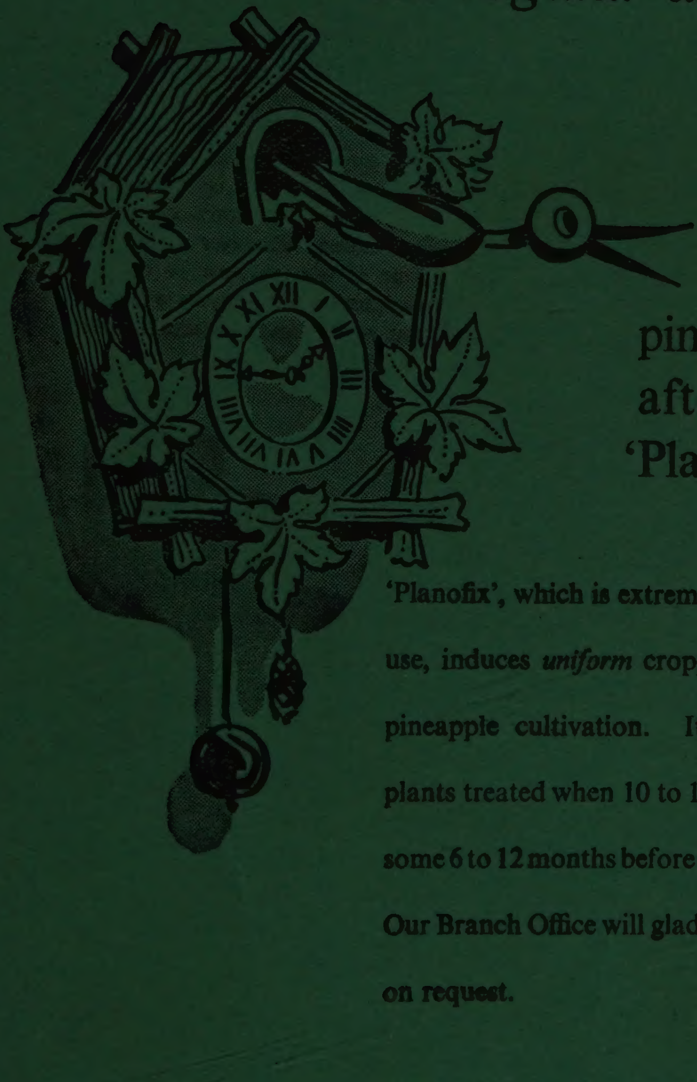

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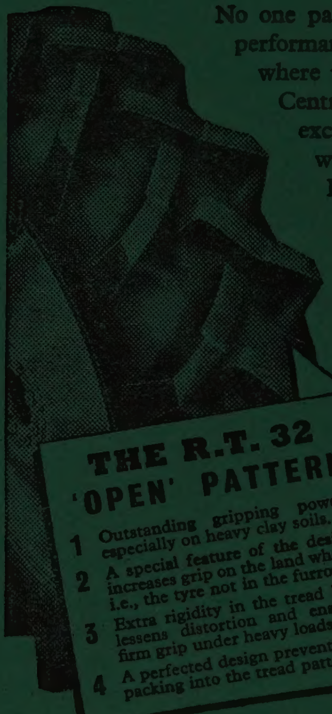

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